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S. HRG. 100-93

REAUTHORIZATION OF THE NATIONAL SCIENCE FOUNDATION

HEARING

BEFORE THE

COMMITTEE ON LABOR AND HUMAN RESOURCES UNITED STATES SENATE

ONE HUNDREDTH CONGRESS

FIRST SESSION

ON

EXAMINING PROPOSED LEGISLATION AUTHORIZING FUNDS FOR THE NATIONAL SCIENCE FOUNDATION

APRIL 9, 1987

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REAUTHORIZATION OF THE NATIONAL SCIENCE FOUNDATION

THURSDAY, APRIL 9, 1987

U.S. SENATE,
COMMITTEE ON LABOR AND HUMAN RESOURCES,
Washington, DC.

The committee met, pursuant to notice, at 2 p.m., in room SD-430, Dirksen Senate Office Building, Senator Edward M. Kennedy (chairman) presiding.

Present: Senators Kennedy and Stafford.

OPENING STATEMENT OF SENATOR KENNEDY

The CHAIRMAN. Come to order.

Our hearing today on the National Science Foundation is well timed since this is "National Science and Technology Week". As the nation focuses on Science and Technology we in the Senate will also.

I hope that some of you had a chance to see the National Science-Technology Center's exhibit "millions" that was in the Rayburn Building for National Science and Technology Week. For those of us who have to deal with the national budget that was very helpful.

This may be a watershed year for the NSF. The Administration seems to have finally come to appreciate what those of us who have supported the NSF for so long have said, that the advancement and growth of our nation depends on a strong base in science and technology research and education. During this 100th Congress there has been a great focus on U.S. productivity and competitiveness. I think it is important for us to look at our own growth and trends over the past years. To look at our own national goals and aspirations, and our own values, to set our priorities with a view of the long range goals we have for our nation's future. As we look at our position relative to other countries, we must acknowledge science and technology as a cornerstone of our economic well-being.

As we move toward the 21st century we must commit ourselves to revitalizing the building blocks of Science and Technology. This requires the support of education and training, the renewal of our university research laboratories and the development of innovative approaches to bring together scientists and engineers. The effects of advances in science and technology are in evidence all around us. Here in the Senate all of our offices now use computers for everything from inter-office communications to correspondence. On Wall Street, the technology of computers has quickened the pace of

financial transactions. In new fields, such as biotechnology we see advances in instrumentation which enable us to learn more about the basic structure of genes, like the gene for Familial Alzheimer's Disease or to produce large quantities of genetically engineered proteins like human growth hormone. Only a few weeks ago a new superconducting material was found which may enable even more exciting advances in electronics.

The National Science Foundation has a profound impact on the science and engineering research and education in the United States. Although the National Science Foundation's budget is only a small fraction of the country's research and development efforts, its role is central. It fosters the development of the wide spectrum of basic science and engineering research and most important, it educates our future scientists and engineers.

We must reverse the decline in our pool of future scientists and engineers. We must also ensure our future in new fields of research and in transferring this technology to improve our nation's economic growth and productivity. At a time of limited funds, wise and strategic investments in science and engineering research and education can bring returns which far exceed the initial realm of possibilities.

OPENING STATEMENT OF SENATOR STAFFORD

Senator STAFFORD. Today the Senate Labor and Human Resources Committee turns to the consideration of the reauthorization of the National Science Foundation. I would like to take this opportunity to thank Senator Kennedy for scheduling this hearing. It has been a busy time for all of us, but any effort in support of the National Science Foundation is time well spent.

We are all aware of the national problem of coping with rapidly changing technology and labor force requirements, as well as a pressing national need to improve our international economic competitiveness. These problems demand a response at the Federal level. When we first started considering this matter over three years ago, Americans were concerned about the problems with science and mathematic instruction in our schools. While improving science and math education is still an issue with which our committee is occupied, today these concerns have greatly expanded. It is appropriate that we look seriously at the reauthorization of the National Science Foundation in order that we might reinforce the NSF's extensive efforts in the crucial areas of education and basic research in science and engineering. I am strongly in support of a multi-year authorization for NSF so that the foundation can engage in long range planning instead of having to produce a one year authorization bill each year.

I look forward to hearing the testimony prepared by the Director of the National Science Foundation, Mr. Erich Bloch, as well as the distinguished panel consisting of Dr. LeRoy Lee, Dr. David Marker and Dr. Robert M. Rosenzweig, and I would like to take this time to compliment Mr. Bloch on his leadership at the Foundation.

As we all know, this week is National Science and Technology Week. I have the privilege of reading the following letter from President Reagan. I ask that this be inserted into the record.

[The letter referred to follows:]

THE WHITE HOUSE

WASHINGTON

National Science and Technology Week

April 5 - 11, 1987

I'm happy to send warmest greetings to everyone celebrating the excitement and challenge of science and technology in our national life.

We Americans have always been a Nation of achievers and innovators in science and technology. New products and inventions by Americans through the years have revolutionized the world. To continue this proud tradition and to maintain our economic competitiveness, we need to keep a strong base of scientists, engineers, teachers, and students who can discover and use new knowledge to create new and better products, processes, and services.

That's the way to a better, more prosperous future for our country and for all the world. And that's why I'm delighted to commend the public-private partnership of the National Science Foundation and private sector groups that sponsors National Science and Technology Week, and to encourage students, teachers, parents, and all Americans to take part in this worthwhile event.

Ronald Reagan

The CHAIRMAN. Without objection, the statement of Senator Hatch will be inserted at this point.

[The prepared statement of Senator Hatch follows:]

STATEMENT OF SENATOR HATCH

FULL COMMITTEE HEARING: NSF AUTHORIZATION FOR FY 1988

APRIL 9, 1987

Mr. Chairman, I want to commend the Administration for its recognition that science and technology are of critical importance to America's future, and for recommending a long-range plan for broadening our basic research base through the programs of the National Science Foundation.

This may be one a few areas of the federal budget which deserves such a hefty increase. Clearly, our nation cannot become more competitive with our trading partners, prosper economically, or improve our citizens' quality of life without scientific and engineering research. It is appropriate that we are holding this hearing during National Science and Technology Week. The activities taking place during this week serve to help Americans become more aware of these connections between science and everyday life.

But the purpose of this hearing is not solely to promote the merits of basic research or of the National Science Foundation. It is to examine the next fiscal year's plan to carry out our mutual objectives-- excellence in research and a broadening of our research base for the future. I have strongly supported many of the specific initiatives of the Foundation,

including programs for women and minorities, instrumentation, science education, and undergraduate science. I continue to be interested in these areas, and am anxious to learn about their progress.

I thank for Chairman for his scheduling of this hearing, and look forward to working with him on a legislation which helps move America forward in science and engineering.

The CHAIRMAN. Senator Stafford?

Senator STAFFORD. Thank you, Mr. Chairman.

Today the Senate Labor and Human Resources Committee turns to the consideration of the reauthorization of the National Science Foundation. I would like to take this opportunity to thank Senator Kennedy for scheduling this hearing. It has been a busy time for all of us, but any effort spent in support of the National Science Foundation is time well spent.

We are all aware of the national problem of coping with rapidly changing technology and labor force requirements, as well as the pressing national need to improve our international economic competitiveness. These problems demand a response at the Federal level. When we first started considering this matter over three years ago, Americans were concerned about the problems with science and mathematics instruction in our schools. While improving science and math education is still an issue with which our Committee is occupied, today these concerns have greatly expanded. It is appropriate that we look seriously at the reauthorization of the National Science Foundation in order that we might reinforce the National Science Foundation's extensive efforts in the crucial areas of education and basic research in science and engineering. I am strongly in support of a multi-year authorization for NSF so that the foundation can engage in long range planning instead of having to produce a one year authorization bill each year.

I look forward, Mr. Chairman, to hearing the testimony prepared by the Director of the National Science Foundation, Mr. Erich Bloch, as well as the distinguished Panel consisting of Dr. LeRoy Lee, Dr. David Marker and Dr. Robert M. Rosenzweig, and I would like to take this time to compliment Mr. Bloch on his leadership at the Foundation.

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That's the way to a better more prosperous future for our country and for all the world. And that's why I am delighted to commend the public-private partnership of the National Science Foundation and private sector groups that sponsors National Science Foundation and Technology Week, and encourage students, teachers, parents, and all Americans to take part in this worthwhile event. Signed by President Ronald Reagan.

Mr. Chairman, I would ask unanimous consent that a statement by the ranking member of this Committee, Senator Hatch, be made a part of the record just prior to my own statement.

The CHAIRMAN. Fine.

If Mr. Bloch will indulge me, I see my niece, Kim Smith's class, they're an eighth grade class, in the back of the hearing room today. They've come down here to listen to you, the Director of the National Science Foundation, Mr. Bloch. And it is very appropriate that they have an opportunity to listen to your testimony because

what you are doing obviously is going to impact on their lives for a very important period of time. We want to thank you very much.

Mr. Bloch is the Director of the National Science Foundation. Prior to that, he was Vice President of Personnel and Development at IBM. He is himself an engineer and was awarded the National Medal of Technology by the President.

Mr. Bloch has taken a very strong leadership role at the NSF, and at a time of scarce resources, to see that the NSF is able to gain support for increased funding is a real tribute to Mr. Bloch and I might say to the President.

I really look forward to your testimony.

STATEMENT OF ERICH BLOCH, DIRECTOR, NATIONAL SCIENCE FOUNDATION, WASHINGTON, DC, ACCOMPANIED BY DR. JOHN H. MOORE

Mr. BLOCH. Thank you very much, Mr. Chairman and Senator Stafford. I hope, Mr. Chairman, that I do not disappoint your niece. Otherwise, she might not come back next year. I have a detailed statement which I would like submitted for the record. Before I start with my oral statement, I want to introduce the Deputy Director of the National Science Foundation, Dr. John Moore, who is here with me at the table.

I would like to respond for a minute about the National Science and Technology Week comment that you mentioned a minute ago, Mr. Chairman. Your Committee deals with human resources, and that is also the theme and purpose of National Science and Technology Week. The whole idea is to excite young people about science and mathematics, keep them interested in these subjects in school, and get them interested in science and engineering as possible careers.

I want to thank the Committee for its support in the past and especially you, Mr. Chairman, and Senator Stafford. With that, let me get started.

I would like to address several key issues and questions this afternoon. The first one is economic competitiveness.

For too long we have tended to see our economic problems as the result of forces that are largely beyond our control, such as unfair trade practices, low wages in other countries, or unfavorable exchange rates.

This concern with economic competitiveness makes us realize that the most important thing is simply just to stay ahead of our competitors. We can succeed if we look to our own resources, of which the most important are new knowledge and well educated people. These are the key elements of a competitive economy.

New knowledge is important because it provides ideas for the new products that we need to compete in high technology areas as well as in manufacturing and service industries.

Education is important because talented and well trained people are the source of any nation's competitive advantage. They produce the new ideas needed for competitiveness and then put them to work in the marketplace.

New knowledge and education are prerequisites for economic strength. Obviously other factors contribute to it, but these are fundamental to everything we do.

Where does NSF fit in in this picture of economic competitiveness? The Foundation is the only Federal agency with such comprehensive responsibility for basic research and education. NSF encourages research on the boundaries between established disciplines, where some of the most economically significant problems arise. Mathematics, science and engineering education are supported at all levels. And I will come back to that particular point in more detail with ways that link education and research and how cooperation between universities and industry and Federal, state, and local governments is encouraged.

NSF also supports programs for developing institutions and regions and programs to increase participation by minorities and women in science and engineering. It's a major strength of our system that basic research and education take place together in our universities. Therefore it is essential that we increase our investment in education and basic research. This is the central idea for the fiscal year 1988 budget request of the Foundation.

Despite the fact that the Federal R&D has almost doubled over the last seven years and the Foundation's budget has followed a similar path, we still have very serious problems with research and education.

When compared with our trading partners, the United States ranks only fourth among the industrialized countries in the fraction of gross national products invested in civilian research and development.

Our students generally do not do well in international tests, ranking consistently below Japan and the Soviet Union in subjects like geometry. Twenty years ago we led the world in the fraction of our population engaged in science and engineering. Today, our competitors have caught up to us. The fraction of Federal R&D that goes to basic research and to universities has been dropping as a percent of the total Federal R&D budget despite the increases the National Science Foundation's budget has seen over the last few years.

Last, but not least, too few of our students are choosing science and engineering careers and too few of those are continuing to the Ph.D. The conclusion is self-evident. We must invest more in our science and engineering base if we want to solve our economic problems. The Foundation's request for fiscal 1988 is 1.893 billion dollars. That's almost 17 percent above our appropriation for the current year. In addition the Administration, as was mentioned by Senator Stafford, is committed to increases that will double the NSF budget over the next five years. In a significant departure from the past, we have submitted a five year authorization bill for your consideration and for your approval.

These increases, together with the five year authorization bill, are important because they will allow the Foundation to plan rationally for programs that involve long term commitments. Many of our programs make long term commitments to institutions and to individuals. For example, it's true of centers, and it's true of the Presidential Young Investigator Program.

The budget proposal emphasizes three major themes, of which the first is education and human resources. People are our most important resource. I have prepared a chart which you find in front of you.* It shows the support for human resources in science and engineering that the Foundation will give in 1988. It ranges from senior scientists all the way to high school students in very significant large numbers.

Our budget proposes a 50 percent increase for education and human resources. The Foundation has always been involved heavily in education efforts, but this year's proposal represents a much broader commitment.

In 1983 science and engineering education programs were only 1.5 percent of the Foundation's budget, a low point. In 1988 these programs will be 6.1 percent of the total, and they will grow more rapidly, as our budget doubles over the next five years, more so than the Foundation's budget would indicate.

You have a second chart in front of you that shows our past and projected expenditures in science and engineering education. It is a projection from 1988 through 1992.

I also want to point out on this particular chart a switch, where before 1980, a majority of our programs were undergraduate programs. Today most of our programs are essentially pre-college programs. In addition, we are starting an undergraduate initiative that I will discuss later.

Just as important as programs are links between education and other programs in NSF, that linkage is important because it ensures that education remains relevant and up to date in this rapidly changing world of science and technology. This is important in our graduate and undergraduate schools. It's just as important at NSF.

In 1987 our education and human resources effort totals $182 million, of which 46 percent is spent through the research directorates. In 1988 the total will rise to $273 million, with 58 percent in the research directorates. All together education and human resources activities will be over 14 percent of the total NSF budget in 1988. These numbers demonstrate both commitment and linkage.

As you know, the National Science Board, the Science and Engineering Education Advisory Committee, and academic groups have recommended much stronger undergraduate programs. We have listened to this advice. And the increase that you see of $38 million for undergraduate programs will more than double the funding for those areas.

Outside of the undergraduate area, we will increase human resources support by $53 million. This will support greater efforts at the pre-college level, an increase of 200 graduate fellowships, more support for Presidential Young Investigators, and renewed efforts to encourage greater participation by minorities, women, and disabled persons.

These are important programs. They demonstrate the Foundation's role in the nation's science and engineering education. But that role must be kept in perspective, especially at the pre-college

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* The charts referred to in text appears with the prepared statement of Mr. Bloch.

level. The Foundation provides less than a tenth of a percent of the nation's overall education budget. For science and engineering education alone, it is still much less than one percent.

At the pre-college level, the states and local governments have the main responsibility. In a few areas with great leverage like television programming and curriculum development, the Foundation can provide a significant fraction of the resources.

But generally that is not the case. We cannot equip the nation's school laboratories or train all the teachers. We can stimulate, we can exemplify, and we can demonstrate, as we do with modern teacher training programs, for example. But the basic resources must come from the others.

At the undergraduate level and above, the Foundation's role becomes more central. The content of science courses becomes more specific, laboratory experience with modern equipment becomes more important, and we are dealing more with potential scientists and engineers.

This is even more true at the graduate level, where large numbers of students are supported on NSF awards, and much of the training consists of actually performing research.

The second theme that we have as part of our overall budget is science and technology centers and groups. There will be additional engineering research centers and centers for biotechnology, materials science, and computer and information sciences.

These centers will be located at universities. They will be multidisciplinary, and they will be organized with strong industry involvement. They will do basic research on problems that are important to science and important to competitiveness.

The centers have both innovative and traditional characteristics. There is nothing new about large grants for organized research programs. We have done that in the past.

There's nothing new about multidisciplinary research. All the major centers are multidisciplinary to some extent. But the emphasis on cooperation between the academic and industrial sectors is new. We are also applying this concept in new areas and extending it to areas of science and engineering where we previously have had a pattern of single investigator support.

With centers, we now have another way to provide resources to universities, but it is all in support of the mission of basic research and education.

Finally, the third area is disciplinary research and facilities, the steady improvement of the Foundation's broad support for these programs and facilities. These will be increased by about $100 million.

This is important because, by its nature, basic research is unpredictable. The comment that was made before on superconductive materials illustrates this. Superconductivity is a breakthrough that occurred in the last few weeks. Nobody would have predicted it probably even a year ago.

Support for centers and support for disciplinary programs are complementary ways to support research. Neither should be over- or under-emphasized. It is a matter of striking the right balance. There is a need for an effective research enterprise, and both serve that purpose.

Mr. Chairman, the President announced recently a major initiative to set the United States on "A Quest for Excellence." He said that our policies must serve three objectives. They must generate new knowledge in science and technology. They must swiftly transfer that knowledge to the marketplace. And they must expand our nation's talent base in science and engineering.

These objectives will be met in part through the programs of the National Science Foundation. But they are long term challenges. It will be achieved only by a long term commitment to strengthen our science and engineering base. The significance of this budget, especially over five years, and the authorization bill request for five years, makes that particular commitment, a long term commitment.

Thank you very much.

[The prepared statement of Mr. Bloch and responses to questions submitted by Senators Kennedy and Pell follow:]

TESTIMONY OF

MR. ERICH BLOCH

DIRECTOR, NATIONAL SCIENCE FOUNDATION

BEFORE THE

LABOR AND HUMAN RESOURCES COMMITTEE

--UNITED STATES SENATE

THURSDAY, APRIL 9, 1987

MR. CHAIRMAN AND MEMBERS OF THE COMMITTEE:

Good afternoon. I am glad to have the opportunity to provide an overview of the National Science Foundation's budget proposals for 1988, to discuss their relation to the nation's economic competitiveness, and to discuss a few additional topics of particular interest to this committee.

First, let me express appreciation for the continued support that this committee has shown for the importance of education and basic research in science and engineering. Your understanding of the links between research, education, and the welfare of our nation has been demonstrated by your willingness to recommend the needed investments in these areas which are important to advancing our economic competitiveness position.

It is high time that economic competitiveness moves to center stage. For too long we have tended to see the source of our economic problems as the result of unfair trade practices, or low wages in other countries, or unfavorable exchange rates.

Recently we have realized that if we want to compete successfully as a nation, the most important thing is to stay ahead of our competitors in continually generating new ideas through basic research, and turning them into high quality, innovative products and services for the market place. Many forces must come together

to achieve economic competitiveness, but prerequisite is a viable infrastructure that is capable of educating our people and generating new knowledge.

Basic Research and Competitiveness

Colleges and universities are the principal instruments for development of these assets. They provide ideas and new knowledge for the products that we need to compete in high-technology areas, and the concepts and ideas that can raise productivity in low-technology manufacturing and service industries.

In fact, technological innovation achieved through research has been responsible for nearly half of all productivity gains since World War II. Research results can take their place side by side with economies of scale and other productivity enhancement parameters.

Many of NSF's programs can be directly tied to these driving forces: robotics, engineering research centers, biotechnology, materials research, education of future scientists and engineers, and many more. Seeking productivity through research and technological innovation is the way we should enhance our position in international and economic competitiveness. It is far preferable to reliance on trade barriers or other protectionist measures.

The Science and Engineering Enterprise

The science and engineering research base on which we depend consists of three elements: people, facilities, and equipment. Of the three, people are by far the most important. Well trained people are the source of the ideas and the knowledge which make technological innovation possible. A dynamic, productive economy demands a steady flow of new ideas and well-educated people to generate successful products.

Adequate facilities and equipment can be obtained relatively quickly -- it only takes money. The creation of a scientist or engineer takes many years--the process begins in the precollege years and continues through undergraduate and graduate training.

The length of time this requires makes it imperative that we continuously attract the most talented young students into science and engineering programs. Interruptions in this process take many years, even decades to overcome.

We cannot depend on market demand to ensure an adequate supply of scientists and engineers, for the market fluctuates much too

rapidly. The educational system cannot respond quickly when demand goes up, and finds itself producing surpluses when demand is down.

The Role of NSF

The government's ability to affect our competitive position is limited, since for good reasons much of the initiative and responsibility rests with the private sector. There is one area, however, in which the government's role is both necessary and clearly beneficial: the support of education and basic research. That is why the National Science Foundation plays an increasingly critical role in the national quest for economic competitiveness. NSF does this by providing linkages among the vital elements of the science and engineering enterprise:

- NSF not only supports research, but education;
- It not only support basic research in the sciences, but also in engineering;
- It supports the nation's top research universities, but reaches out to undergraduate institutions, high school and elementary schools as well; and
- It does not operate in isolation but demands the active involvement in both planning and funding of private sector entities, state and local governments, and universities themselves.

The FY 1988 Request

Our budget request for Fiscal Year 1988 is $1.893 billion. That is a substantial 16.7% above our appropriation for the current year. Of equal importance, the Administration is committed to increases at a rate that will double our budget, to a level of 3.2 billion dollars, by 1992 (Chart 1).

These increases, projected over a five year period, establish a strong base from which to expand support for education and university basic research and plan for the future. This is a major departure from the past. It reflects the need to rebalance our effort in research and development. This cannot be done in one year alone. It also reflects the nature of education and research--many of the proposed programmatic thrusts are spread over many years, even decades. Stability of funding commensurate with the time horizon of programs and initiatives allows for much better planning.

NSF's budget request should not be judged in isolation. It must be considered as part of the total Federal research and development budget, in fact as part of the total U.S. research and development effort (Charts 2-4).

Since 1980, federal support for research and development has nearly doubled, going from $33 billion in 1980 to about $63 billion in 1987. The fraction of the civilian-oriented effort devoted to basic research has risen in that time from about 26% to about 39% With strong bi-partisan support, the overall budget for the Foundation rose 66% between 1980 and 1987, ending a long period in which it was essentially flat.
These actions have been beneficial; but, we are continuing to experience serious problems:

- Basic research is dropping as a proportion of total federal R&D. It is also shrinking in the private sector (Chart 5).
- We see increasing research competition from our trading partners (Chart 6).
- We see shortages of scientists and engineers developing in some fields.
- Our production of scientists and engineers is not keeping up with that of our international competitors. And,
- Facilities and instrumentation in universities need modernizing.

We can only conclude that a significant increase in education and basic research support in our universities is needed.

Our budget proposals for 1988 are focused on dealing with these issues and giving a renewed emphasis to basic research and support for universities.

Three major themes are emphasized in this budget:

- Education and human resources;
- Basic science and technology centers; and
- Disciplinary programs and facilities.

Education and Human Resources

The first theme is education and human resources. The nation's

science and engineering base -- the source of our ability to do basic research and to develop new technologies -- is made up of people, equipment and facilities. Of the three, people are the most important.

I do not need to recite the findings of several recent national studies and international comparisons which highlight alarming shortcomings in our education infrastructure, and in science and mathematics achievement among our students. And we know the demographic data that show us a future with proportionally fewer young people, our most basic resource. We must act to address these serious concerns about the quality and quantity of the talent pool we need to sustain a vital scientific and technical enterprise in this nation.

The National Science Foundation proposes significant growth in support for education and the development of human resources, from $182 million in FY 1987 to $273 million in FY 1988.

Attention is given to the precollege, undergraduate, and graduate education areas. NSF has different responsibilities at each of three areas of the educational spectrum.

In precollege education, the feeder for all science and engineering talent for the country, the center of gravity of support and policy is in the thousands of localities across the country, the state governments, and--on the federal level--at the Department of Education. Yet our influence can be large. Our programs are designed to catalyze, to demonstrate, and to mobilize interest from other participants. The Foundation's resources are small compared to the total resources available and need to be judiciously applied. For FY 1988, the President's mandate that NSF, in conjunction with the Department of Education, address mathematics, science, and computer literacy for the country's children will be a major focus.

Areas of NSF emphasis are ones where the potential for significant leveraging of our investment is present. Examples include:

- New materials development;
- Inservice and preservice teacher training;
- Early experiences to stimulate interest in science and engineering;
- Informal (e.g., television, museums) education beginning at the very earliest school years; and

- Focus and recognition for teaching excellence (e.g., the Presidential Awards for Excellence in Science and Mathematics Teaching).

Foremost however, the involvement of the NSF can guarantee the participation of the university research community in precollege education.

Undergraduate education in science, mathematics, and engineering has been singled out by the recent report to the National Science Board as demanding major attention. NSF's role will be one of focusing on:

- Research experiences for undergraduate students and faculty as part of its disciplinary research projects and centers;

- Curriculum development, beginning with calculus and engineering; and

- Instructional and research instrumentation for use by undergraduate faculty and students.

This is a new approach for NSF with respect to organizing our support for undergraduate research and education in science and engineering. All directorates will have a role and the effort will be coordinated for the Foundation as a whole by the Science and Engineering Education Directorate.

Graduate education has always been a major focus of the Foundation through its prestigious Graduate Research Fellowships Program and its support of graduate students through ongoing research awards. Support beyond the graduate level has included postdoctoral research associates, postdoctoral fellowships where special needs exist, special seminars and conferences, research initiation efforts, and the Presidential Young Investigators program.

Throughout the planning process and the development of the budget request before you, focus has been on balance across the educational spectrum to attract, educate, and retain the technical personnel we need for our future, We have used the principles of excellence and opportunity for participation by all our citizens, regions, and institutions to build a strong, comprehensive approach.

The table below shows the distribution of funds for this effort:

EDUCATION AND HUMAN RESOURCES

Undergraduate	$ 68.0 Million
Instrumentation/Laboratory Development	22.0*
Research Experience for Undergraduates	18.0*
Faculty Enhancement	11.0*
Curriculum Development	7.0
Research in Undergraduate Institutions	10.0

Other Human Resources	$ 205.0 Million
Precollege	68.0
Graduate/Postdoctoral	54.5
New Investigators	52.0
Broadened Participation	30.5

* Planning estimates. Final distribution will depend on proposal pool. Some projects may combine efforts for laboratory instruction, faculty and student development.

Under this effort, existing programs will continue, and expand, and new activities will be supported:

- Precollege emphasis on teachers, materials, advanced technology, and informal science education continues. New activities for high ability high school students will be implemented.

- Support for undergraduate activities more than doubles, with new activities for faculty and curriculum development, and significantly enhanced programs for instrumentation and students.

- 200 additional new Graduate Fellowships will be awarded, and the number of Presidential Young Investigators will increase by 200.

- New activities will be introduced to increase the number of women and minorities participating in science and engineering.

I want to emphasize that this effort in education and human resources will be supported throughout the Foundation. Over the past three years, the Foundation has placed increasing emphasis on addressing significant cross-cutting issues through all its programs. We have developed coordinating mechanisms, and established tracking and monitoring systems. This cross-directorate approach will be followed in the proposed activities for education and human resources.

The Science and Engineering Education (SEE) Directorate will continue its primary emphasis on precollege education, instructional laboratory equipment for undergraduate institutions, and the prestigious program for graduate fellowships (Chart 7). It also has the prime responsibility for bringing the President's mandate referred to above a reality.

I firmly believe that the Foundation's disciplinary research directorates must be responsible for the health of their science and engineering disciplines -- including concern for the underlying education and human resources infrastructure. The most effective activities in this arena will reflect the particular needs of specific disciplines and research areas. Therefore, the undergraduate initiatives, like many of the efforts focused on participation by minorities, women, and the disabled, are distributed across NSF, with central monitoring and fiscal control.

We have already seen the success of this approach in the program for Research in Undergraduate Institutions. The new program for Research Experiences for Undergraduates, introduced just last December, is already drawing enthusiastic response.
It is also important to recall that in addition to these focused efforts for education and human resources, the Foundation continues its substantial support for undergraduate and graduate research assistants on NSF research projects -- fostering in another way the critical link between education and research. In FY 1986, more than $115 million supported over 3,000 undergraduate and 12,000 graduate students in this fashion (Chart 8). This support will grow to an estimated $145 million in FY 1988 through proposed increases for science and technology centers and basic disciplinary research programs.

Basic Science and Technology Centers

The second theme is the establishment of basic science and technology centers. These are university-based, multidisciplinary research centers--each with strong industry involvement--working on problems that are scientifically important and can, in the long term, contribute to advancing our economic competitiveness. This is the program that the President announced in his State of the Union address.

The close coupling of industry with academic research that these centers provide has the potential to substantially improve technology transfer from research labs to industry and to the marketplace.

At the same time, these science and technology centers will play an important part in the education process because they involve

students, both graduate and undergraduate, in research on important problems. The result of that research will find its way into improved curricula.

The proposed $50 million increase will be applied to the establishment of new centers based on the proven concept of the engineering research centers. These would include additional ERC's, biotechnology centers, and centers for materials science, social and behavioral sciences, and computer and information sciences.

Disciplinary Research Programs and Facilities

The third theme of this budget is the steady improvement of the Foundation's traditional broad support for disciplinary programs and specialized research facilities. For these activities, we are proposing an increase of nearly $100 million, with special focus on global geosciences, biotechnology, and materials science and engineering.

Solid support across all the disciplines is important because, by its nature, basic research is unpredictable; one cannot say in advance where a breakthrough with major economic importance will be found. But we know from experience that they will be found. Let me give you an example of that that I found striking: a problem in basic research in astronomy a few years ago was to develop calculations that could determine the properties of objects that are occluded by the moon. No one could have predicted that this same process of calculation would become the basis of an important modern medical technology called computerized axial tomography: the "CAT" scan.

These jumps from basic research to applications can almost never be foreseen, but they have happened so frequently in the past that we can be confident of the ultimate value of the investment.

Now I'd like to discuss several topics of special interest to this subcommittee--the NSF proposal review system, balance in the support of projects, and monitoring our cross-directorate education and research thrusts.

Merit Review

The Foundation is very proud of its competitive proposal review process. The core of this process is the judgment of qualified, experienced scientists and engineers in identifying promising, high quality research and education projects worthy of support. This system has been subjected to periodic examination by internal task forces and outside panels, including Congressional committees. It has been found to be remarkably effective and flexible, adapting to the changing needs of science and

engineering, and incorporating improvements with respect to openness, accountability, equity, and impact on the research and education environment.

At NSF there are more than 200 individual programs managed by some 300 program officers, about a third of whom are on leave from their universities or other organizations. Program officers are recruited for their knowledge and experience and they interact constantly with the research or education community of which they are a part. They are experts in their fields and are well aware of the opportunities and needs in their areas. They administer the proposal review process and use its results to form the basis for their recommendations for support of projects. Their recommendations are, of course, reviewed by higher level officials, and if the award recommended exceeds $1.5 million for one year's support, by the National Science Board.

NSF's review process includes participants from the broad community of highly qualified scientists and engineers--men and women, white and minority, large research institutions and smaller undergraduate-oriented colleges and universities, federal laboratories and industry, and from all geographic regions. We take the fairness issue very seriously and conduct an annual statistical analysis to identify real or apparent biases.

Since 1974, NSF has used four criteria for selecting projects: research performance competence, intrinsic merit of the research, utility or relevance of the research, and effect of the research on the infrastructure of science and engineering. The excellence of the science of engineering being proposed is THE major factor for selection. Once that has been established, the secondary criteria are used. In 1986 the NSF Advisory Committee on Peer Review chaired by Dr. Norman Hackerman, President emeritus of Rice University and former Chairman of the National Science Board, affirmed the fundamental health of the present system. Recognizing the evolution of the perr review process at NSF, it recommended adoption of the term "merit review" as a more accurate description of the present process.

In the last few years there has been an increase in interdisciplinary research proposals. This is a reflection of the growing numbers of research problems which require the combined expertise of scientists and engineers from several disciplines. Such proposals present special problems for a system which has traditionally been structured to handle proposals which are single discipline in nature. Different organizational arrangements for administration and different review procedures are required, as was the case with the Engineering Research Centers Program. The process we instituted involved a multi-stage, interdisciplinary review of ad hoc panelists, a site visit team, and a final "blue ribbon" panel.

Monitoring Project Balance

One of the issues which has recently become of great concern, to many in the academic research community is that of balance among the various modes of support for research. As the area of multidisciplinary research has grown and as the cost of research equipment has continued to increase, we have seen a shift in the proportion of resources devoted to collaborative research projects. As this has happened, concern about the funds that go to individual investigator projects has been expressed.

The facts are that individual investigator awards constitute by far the largest portion of the NSF budget (about 60%), and reflect our commitment to maintaining the basic research capability of the Nation across the full spectrum of science and engineering disciplines. These awards promote flexibility and spontaneity which often foster scientific breakthroughs.

At the same time, much basic research over the past decade has moved in the direction of collaboration and concentration of resources. Much of this change is driven by the nature of scientific inquiry itself rather than just the increasing costs of doing forefront research.

Technologies such as satellite communication and large scale computing and computational techniques enable scientists to work with data sets of greater size and complexity than ever before possible. The leading edge of modern scientific effort is more and more at the intersections of traditional disciplinary boundaries: astrophysics, biotechnology, atmospheric chemistry, materials science and engineering for examples are emerging "fields" which require expertise from more than one discipline.

The fraction of the NSF budget devoted to collaborative research has been growing over the past several years in response to the trends noted above. In many cases, scientists who would have worked alone or with a graduate student or postdoc now find themselves interested in problems which require association with other investigators, and the use of large scale facilities and specialized instrumentation.

Centers such as those initiated under the Engineering Research Centers program are a natural evolution of the trend toward interdisciplinary collaboration to address complex and urgent science and engineering problems. In addition, centers provide unique opportunities for education and technology transfer as well for involving the private sector, states and localities, as active partners.

Let me assure you that this matter of balance is of great concern to us as well. It receives careful consideration at every level,

from individual program to senior management and the National Science Board, and is a major element in the deliberations of our advisory bodies. This year one of the National Science Board's Task Committees is specifically devoted to examining the centers/individual support modes, including the issue of arriving at a proper balance between them.

The continuing rebalancing between centers, groups, individual grants, instrumentation, and facilities is driven by the demands of science and engineering, the emergence of new disciplines and research approaches. The current proportions among these various modes reflect our judgments about the dynamic forces in today's research as well as the fundamental relationships which underpin the long term health and vitality of the science and engineering enterprise. As in all changes, what is the emerging golden age to some, is threatening to others.

Managing Cross-Directorate Efforts

As more and more of the Foundation's efforts become not just multi- and interdisciplinary, but also cross organizational units, the issue of tracking and monitoring our expenditures in these areas becomes very important. We see this in areas such as our distributed minority and women's programmatic efforts, the computational science and engineering initiative, the global geosciences activities, and others. Concerns about tracking and monitoring raise issues of accountability, how we can judge success or failure, and others. Over the past several years we have devoted significant time and effort to designing, developing, and implementing a system that responds to these concerns.

Two types of tracking and monitoring take place: 1)proposals and awards in cross-directorate programs and activities and 2) participation of underrepresented groups in NSF programs and as members of peer review and advisory panels.

With regard to the tracking and monitoring of cross-directorate proposals, the experience we have gained in mainstreaming the research in predominantly undergraduate institutions initiative,Minority Research Initiation and Research Opportunities for Women programs has paid significant dividends in extending the concept to other NSF programs. In 1987, the tracking system has been extended to include Research Experiences for Undergraduates.

New procedures for coding proposals have been established are now in place throughout the Foundation. Our Management Information System now generates detailed monthly reports on cross-directorate activities. These reports are used by program and division level staffs to monitor their progress in meeting funding targets for special program activities. Quarterly

reports are prepared to assess progress toward targets across the Foundation. These are discussed at directorate quarterly reviews and at Executive Council. One aspect particularly important to note is that this system now allows us to electronically designate funds to be used only for the purposes of these special activities.

For the first time, we have in place a system that allows us to monitor on a real-time basis the specialized characteristics of the proposals we receive and the awards we make. We intend to use this basic coding scheme to track our efforts in other areas such as computational science and engineering, biotechnology, and global geosciences.

For some time we have discussed with this committee our efforts to obtain information on the representation of women, minorities, and disabled persons as proposers, awardees, peer reviewers, and advisory committee members. Our progress has been slower than we would have hoped but I am pleased to tell you that the system is now in place, operational, and we are able to extract data from it.

In December 1985 NSF issued an important notice to colleges and universities requiring the submission of a form which records data on gender, ethnicity, and disability status. The submission of the data is voluntary, submission of the form is not. After a complete year's experience, we now know that for gender data, the response rate for submitting the data was 99% and the percentage of proposals submitted by female investigators was 12%. Similarly we know that the response rate for racial/ethnic data was almost 90% and about 2% percent of the proposals were submitted by minorities underrepresented in science and engineering.

In a related vein, in January 1987 NSF issued an important notice to colleges and universities about the collection of data about personnel who received support on NSF awards. As a part of the final project report required for every NSF award, summary data will be submitted on PI's, postdoctorals, graduate and undergraduate students, precollege teachers, and foreign students. Summary statistics will be available by gender, race, and disability. While it is obviously too soon to predict what sort of information we will get, we are encouraged by the cooperation that we have received from the academic community on our previous data collection efforts.

Summary

In summary, the NSF budget for Fiscal Year 1988 and future years will allow the Foundation to improve research and education in our universities and colleges in very important ways through:

- o basic science and technology centers;
- o mathematics, science, and engineering education at all levels of the educational pipeline;
- o broader participation of institutions and underrepresented groups;
- o cooperation between federal and state governments, industry, and academia; leveraging taxpayers' dollars in the process; and,
- o transfer of research results from universities to industry.

Mr. Chairman, all these activities are important for the long term economic health of our nation. Through them, the Foundation will make significant improvements in research and education at our universities and colleges.

Even more important, the Administration's commitment to doubling of the NSF budget will keep education and basic research in science and engineering on a steady upward track. I believe strongly that nothing is more important for the long term economic health of our nation. I look forward to working with you and with the entire Congress to make sure that these proposals are turned into actions.

NATIONAL SCIENCE FOUNDATION
OBLIGATION TRENDS

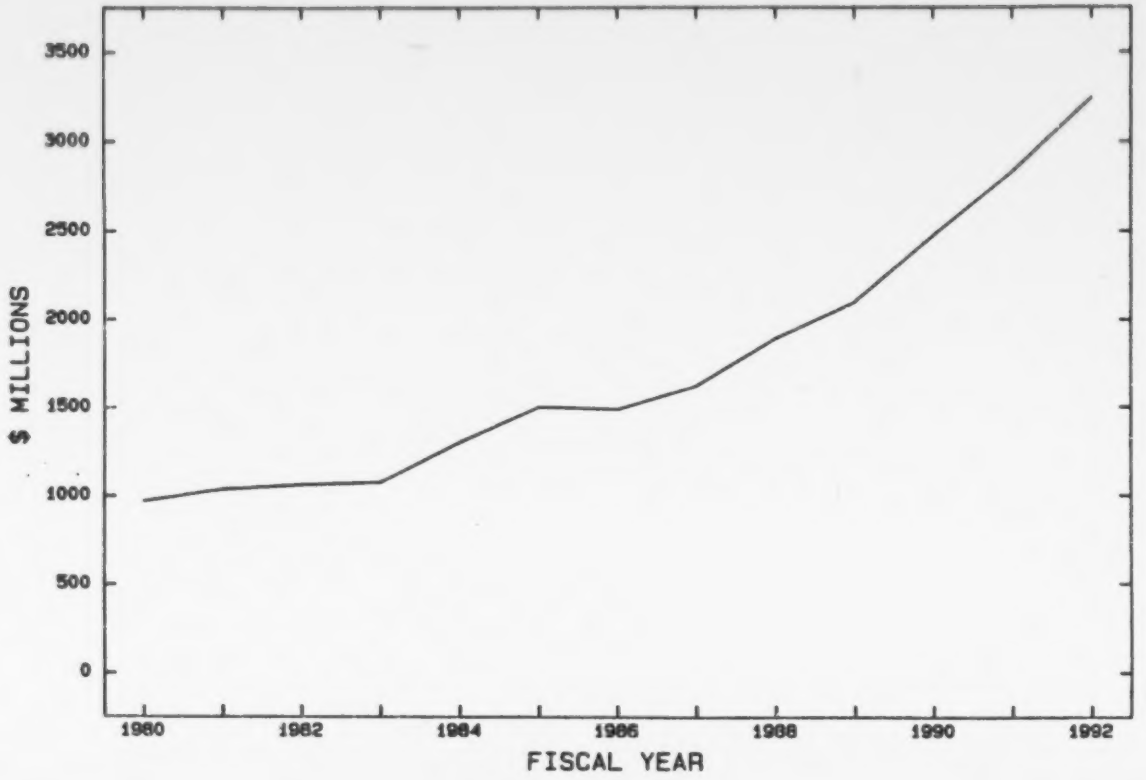
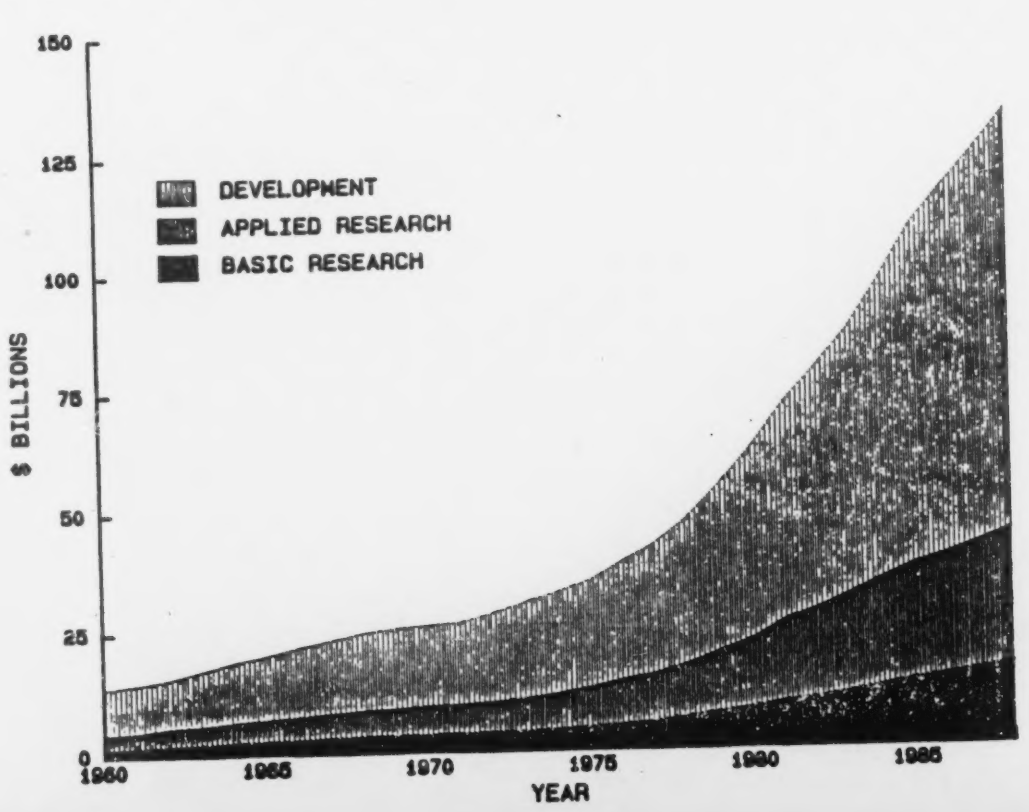


CHART 2

NATIONAL EXPENDITURES FOR RESEARCH AND DEVELOPMENT



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Research and Development
1987

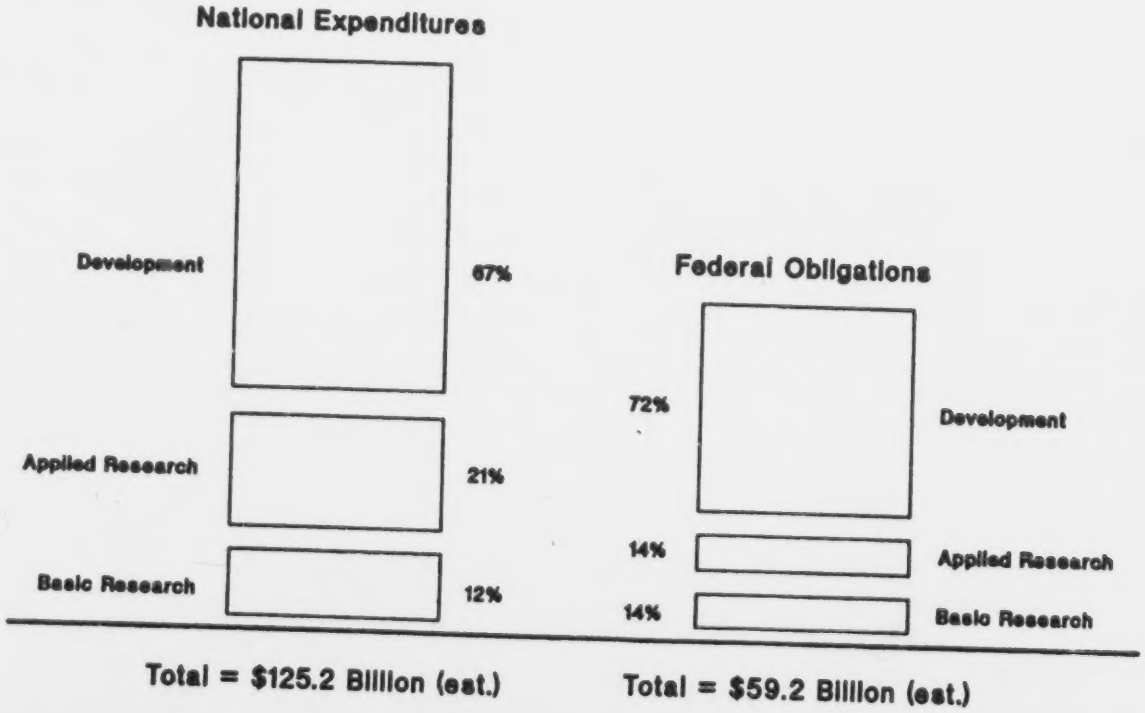
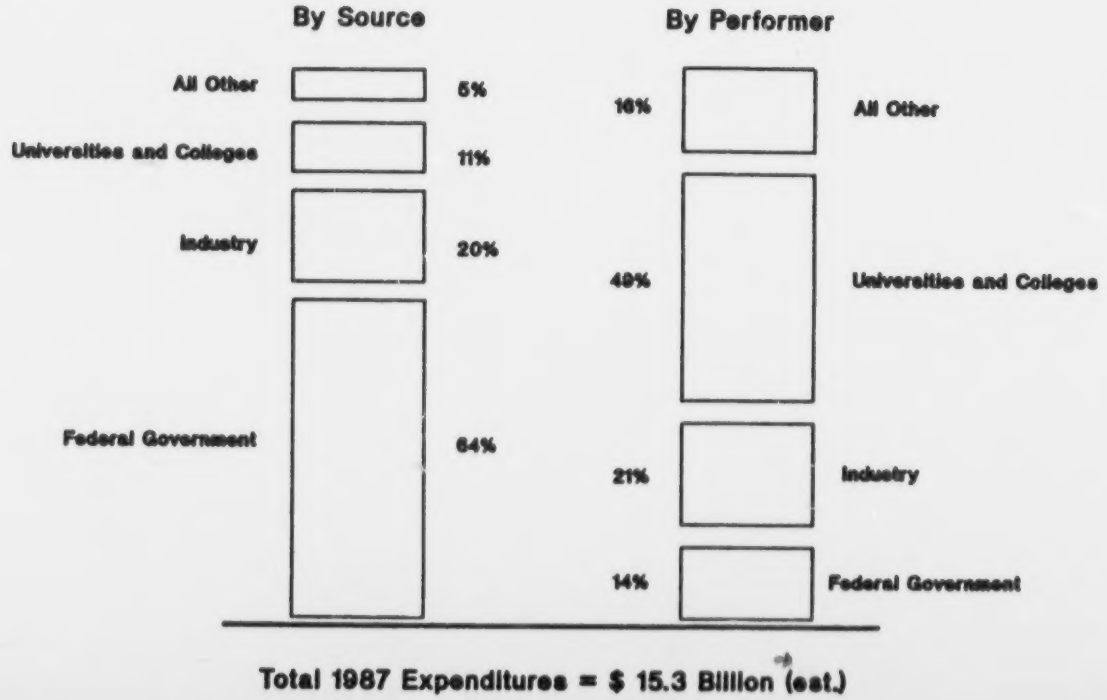


CHART 4

National Expenditures for Basic Research



Total 1987 Expenditures = $ 15.3 Billion (est.)

CHART 5

BASIC RESEARCH
— AS A PERCENT OF TOTAL R&D —

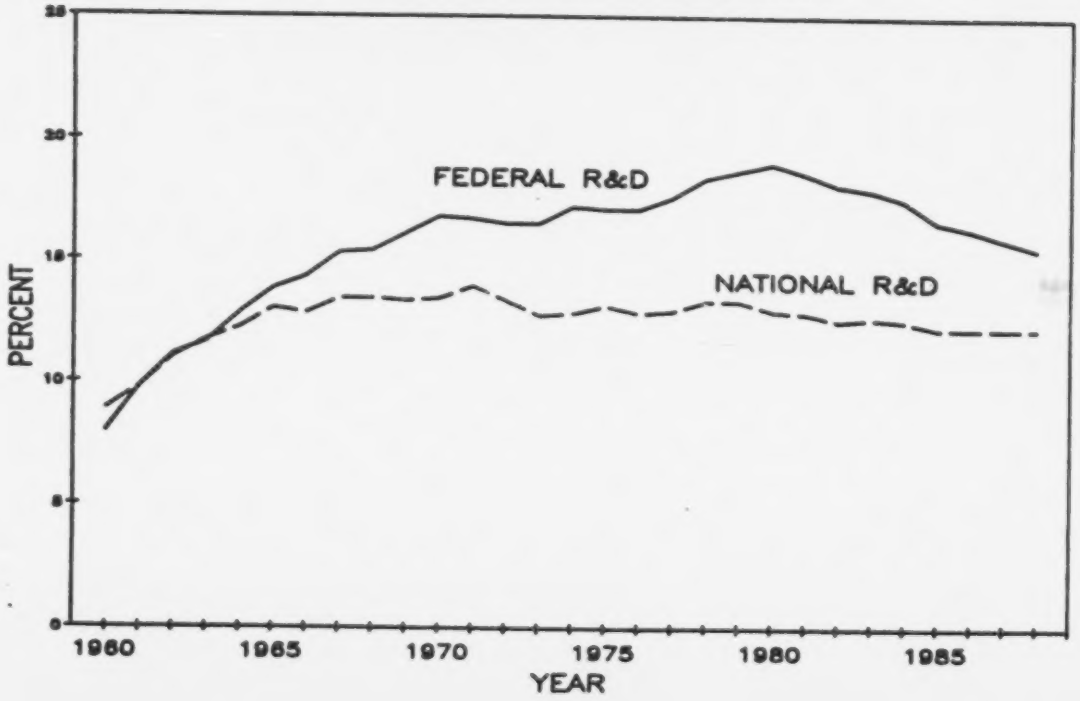
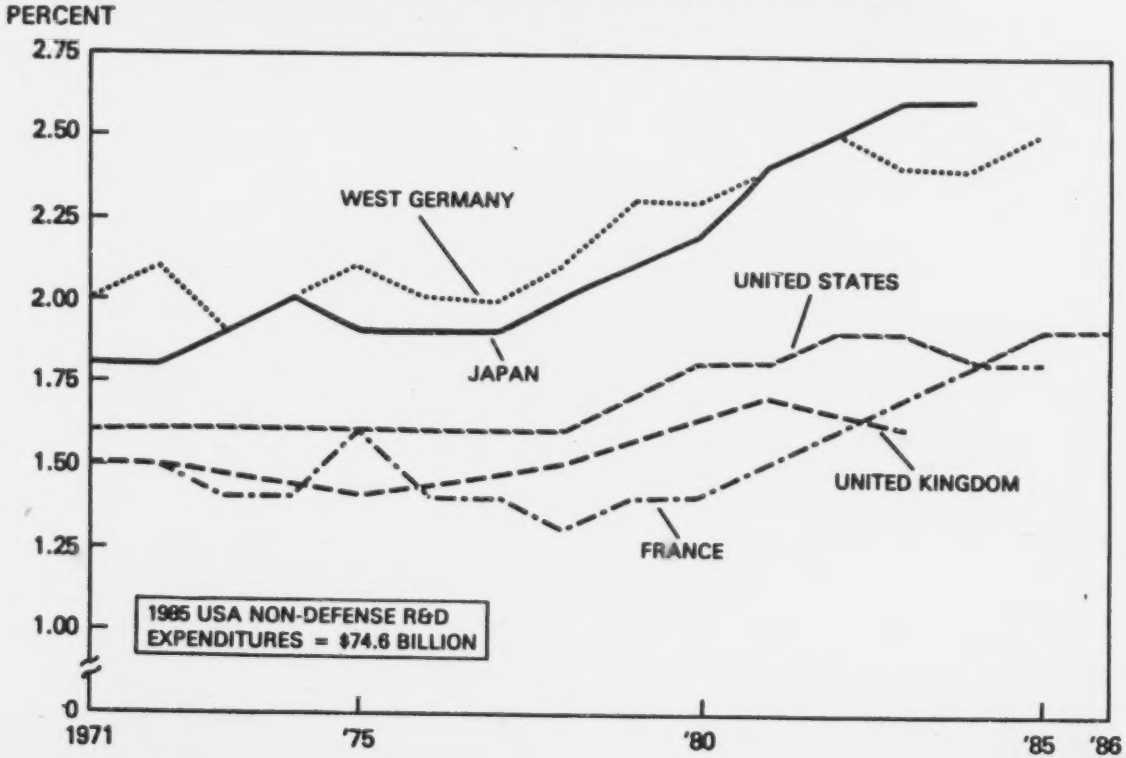


CHART 6

NON-DEFENSE R&D EXPENDITURES AS A PERCENT OF GROSS NATIONAL PRODUCT (GNP) BY COUNTRY



SOURCE: DIVISION OF SCIENCE RESOURCES STUDIES.

CHART 7

NATIONAL SCIENCE FOUNDATION

SCIENCE AND ENGINEERING EDUCATION DIRECTORATE OBLIGATION TRENDS

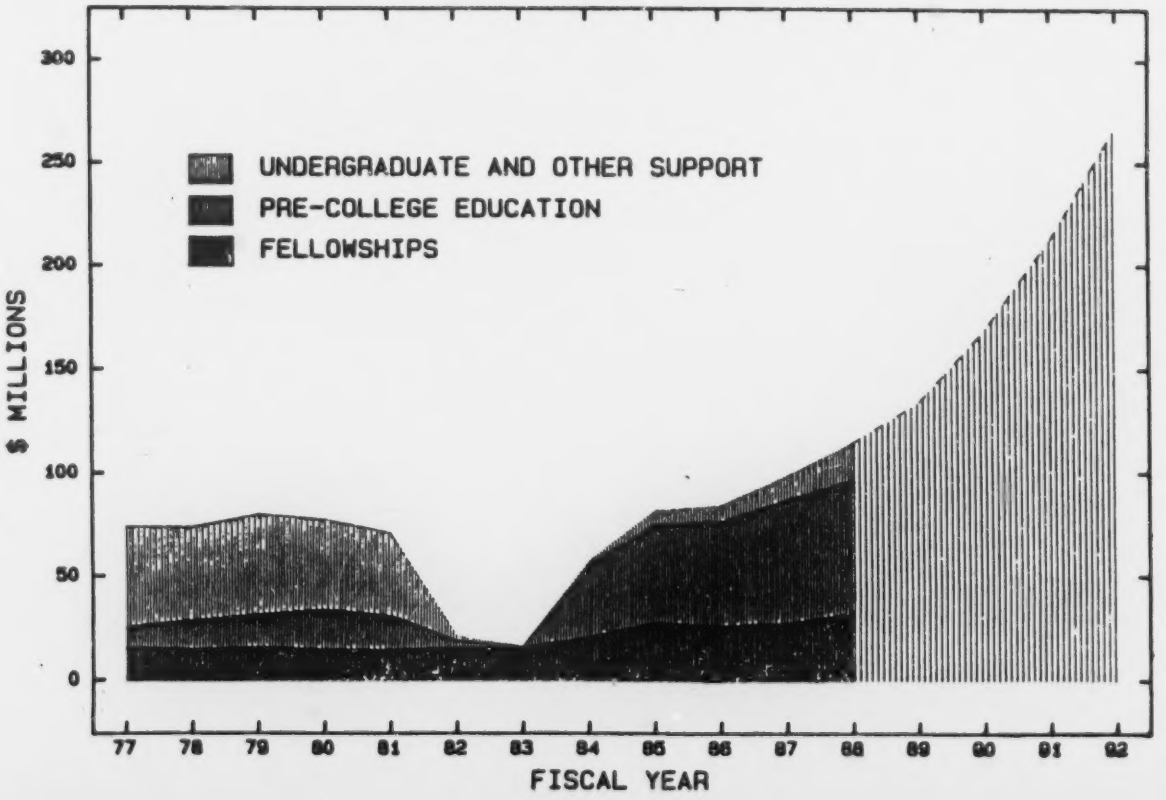
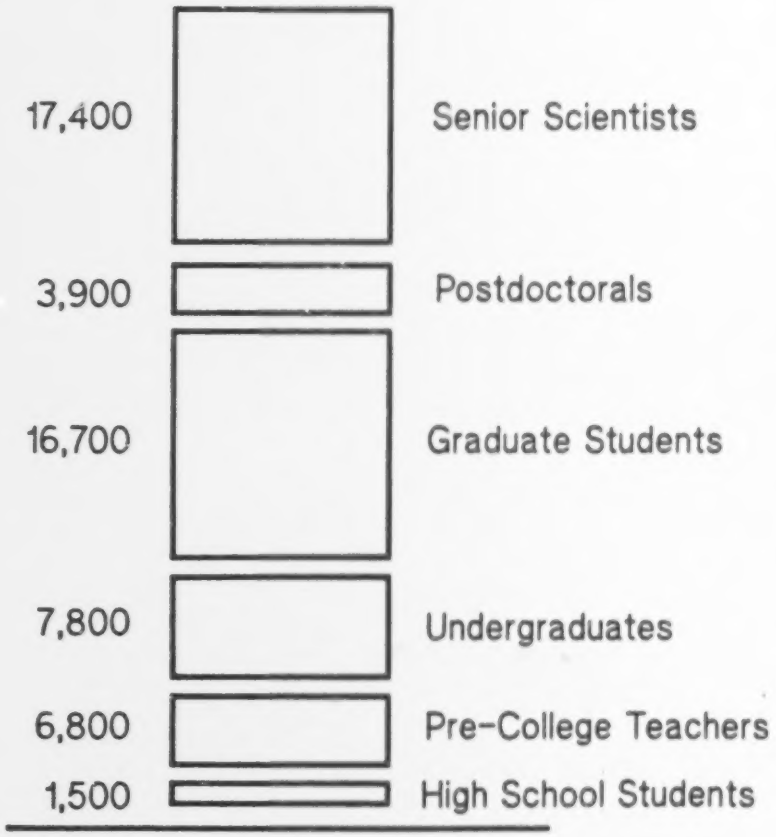


CHART 8

National Science Foundation Support for Human Resources in Science and Engineering

Fiscal Year 1988



QUESTIONS SUBMITTED FOR THE RECORD BY SENATOR KENNEDY

Question: Mr. Bloch, I want to commend the National Science Foundation for its proposed increase in funds for undergraduate science and engineering education. Would you describe your reasons for putting these programs in the research directorates and would you clearly define the role of the Office of Undergraduate Education which you established in the Education Directorate?

Answer: The role of the research directorates in undergraduate education is based on our conviction that education and research priorities and needs are closely linked, and that the most effective educational activities will reflect the particular needs of specific disciplines. Our plans build on successful experience with coordinated programs that operate across directorates, such as the Research in Undergraduate Institutions (RUI) program initiated in FY 1984, and the new Research Experiences for Undergraduates (REU) program initiated in FY 1987.

Overall, responsibilities for planning, developing and implementing undergraduate activities are shared between the programmatic research directorates and the Directorate for Science and Engineering Education (SEE), with SEE having responsibility for coordinating undergraduate activities across the Foundation. We presently are studying appropriate roles, functions, staffing levels, and other matters related to the establishment of an office of undergraduate education in SEE. It is clear, however, that a key role of this office will be tracking and monitoring undergraduate activities across the Foundation, including the provision of periodic reports on these efforts.

Question: We in the United States pride ourselves on our basic research capacity. Many foreign scientists come here to study and train. Other countries, such as Japan, are also developing advanced science and technology. What is the NSF doing to help U.S. scientists gain access to foreign research information?

Answer: On March 15, NSF's Division of International Programs in the Directorate for Scientific, Technological, and International Affairs (STIA), established a new unit, the Information and Analysis section. Its purpose is to collect, analyze, and disseminate information on international R&D activities. Its function is to make available to NSF management and to the U.S. scientific and engineering communities information on research throughout the world.

The new section is headed by an NSF officer who directed NSF's Tokyo office for the last four years, and who was responsible for the preparation of more than 100 reports on Japanese science and

technology. The section includes NSF's offices in Tokyo and in Paris, which prepare special reports.

The section reports on new developments, trends, and events of importance with comment or analysis. It will sponsor state-of-the-art studies by experts, computer-accessed country files, and computer "bulletin boards", for topics of special interest. It is coordinating its activities with the Department of State science officers and other Federal agencies, and is preparing a mechanism to gather reports on matters of special interest from NSF grantees who work or travel abroad.

Question: Even in this country, it is difficult to make existing data available to U.S researchers. Is NSF addressing this problem?

Answer: The Information and Analysis Section is supporting an electronic bulletin board at George Mason University with the Office of Naval Research and the Air Force Office of Scientific Research. It is developing reports on the scientific and technical infrastructure, by country, that will be available through several electronic networks to American scientists and engineers, as well as in hard copy. It is working with the Department of State to provide on-line dissemination of cables from science officers in 25 foreign capitals. It is establishing liaison activities with U.S. scientific and engineering societies and industrial research organizations. These mechanisms make existing data available to U.S. researchers and, through feedback from the research community, will be refined to disseminate such data more effectively.

Question: In looking into the possibility of multi-year funding, would you be able to provide estimates for the directorate budgets for more than one year?

Answer: Yes, provided that reasonable groundrules can be established for periodic re-programming. Because NSF responds to unsolicited proposals, it is difficult to estimate directorate-level budgets for activities that cut across disciplinary lines: the new S&T Centers, for example, will elicit proposals on a wide range of disciplinary and multi-disciplinary topics.

A second factor that can lead to unanticipated budget shifts is exceptional scientific opportunity, such as that currently presented by breakthrough s in superconductivity research.

Question: Mr. Bloch. I have introduced a bill in the Senate on "Star Schools." This bill will facilitate the use of technologies to increase access to science, math and foreign language instruction. Do you think that enabling schools to use new technologies to enhance access to science and math instruction will help us to improve our educational capabilities?

Answer: The National Science Foundation believes that educational technologies have great potential for increasing both the quality and efficiency of science and mathematics education. At the same time, we are familiar with the difficulties in adoption and implementation. Teachers and students need to become familiar with appropriate uses of the technologies, what technology can and cannot do. School administrators and school boards must be convinced of the potential, and willing to invest in new and different instructional tools.

The Foundation is addressing the effective uses of new technologies through support for research to further the state of the art and the potential of new technologies. We also fund development of software to enable students to collect and share, via telecommunications, actual scientific data. We are supporting some instructional television productions aimed at improving science education for the early elementary student. In addition, we are supporting projects to revise the mathematics instruction, taking into account the calculator and computer.

Our teacher development programs are undertaking serious efforts to make teachers more knowledgeable about the benefits of using technologies, and to make them comfortable and skillful in its use.

Overall, we believe that this balanced effort offers the greatest promise that the potential of educational technology can be realized on a large scale.

QUESTIONS SUBMITTED FOR THE RECORD BY SENATOR PELL

Question: I am interested in an update on Soviet participation in the international consortia on ocean drilling. Has a decision been made as to whether the Soviet Union will be allowed to participate? Also, what is the National Science Foundation's position on this matter?

Answer: NSF has informed the USSR Academy of Sciences of the Administration's recent decision that it is not in the country's best interest to pursue participation of the Soviet Union in the ocean drilling consortium at the present time. While the Ocean Drilling Program is a basic science undertaking, it does entail access to sophisticated technology.

The decision should not be interpreted to mean we are not interested in multilateral scientific cooperation with the Soviet Union. Additional bilateral scientific cooperation will continue to be an important part of out general relationship with the Soviet Union.

Question: Unfortunately it is still the case that too few women and minorities are attracted to careers in science and mathematics. What plans does the National Science Foundation have to assure that all Americans will be well-represented in these most important fields?

Answer: The Foundation's FY 1988 budget request includes over $28 million for focused programs and other special efforts for minorities, women and the disabled -- a 50% increase ($ 9 million) over FY 1987. Funding of principal investigators from underrepresented groups is also expected to increase through the Foundation's other research programs.

Two new programs are proposed in FY 1988: Resource Centers at institutions with significant minority enrollments, and Research Career Opportunities projects addressing career choice points for minority, female and disabled students.

Increases are proposed for the Visiting Professorships for Women program, and for Minority Graduate Fellowships. Increases are also proposed for two programs that provide research support to new investigators: Minority Research Initiation and Research Opportunities for Women. Support will continue for two programs to upgrade training and research capabilities at minority institutions: Research Improvement in Minority Institutions and Minority Research Centers of Excellence.

In addition to the focused programs outlined above, attention is given to participation by underrepresented groups through other activities. Supplements are provided for Research Assistantships for Minority High School Students to work with NSF principal investigators. Similar supplements are provided to disabled

students and scientists through Facilitation Awards for the Handicapped. In the Science and Engineering Education Directorate a special solicitation is proposed in FY 1988 for projects in teacher education addressing methods to encourage full participation of minority, female and disabled students in science and mathematics studies.

Question: As you know, the health of our nation's museums has long been a concern of mine. The Arts and Humanities Endowments have been very supportive of projects in art and history for many years. Science museums have, for the most part, fallen through the cracks -- except for the modest operating support provided by the Institute of Museum Services. How is the National Science Foundation helping science museums, and what do you see happening in future years in this regard ?

Answer: The National Science Foundation supports science museums through educational activities in the Directorate for Science and Engineering Education (SEE) and research activities in the Directorate for Biological, Behavioral and Social Sciences (BBS).

Museums have long been on the forefront of efforts to communicate to children and adults alike the joy and excitement of science. Increasingly, science museums are educational partners with schools, providing classes, clubs, and activities for children, science materials and equipment support for schools, and teacher training and development programs.

Support in SEE comes primarily from the Informal Science Education programmatic area, with some projects supported by the Instructional Materials Development and Teacher Preparation and Enhancement activities. This NSF pattern of project support is in sharp contrast to the role of the Institute of Museum Services, whose principal function is to provide supplementary operational support to museums and help reduce their operating cost burdens.

For example, exhibit development grants have supported permanent developments in many of our country's major science museums, including The Exploratorium in San Francisco, which has had a world-wide impact on basic science exhibits. NSF supported the initial development of materials-rich discovery rooms for natural history education for young children, which have been adopted by many natural history museums throughout the country.
The Foundation has supported 24 traveling science exhibitions that will reach more than 100 museums and an estimated 25 million visitors nationwide. Many of these are co-operative projects of museum consortia, whose formation was encouraged by NSF. The Foundation played a major role in the development of the Asscciation of Science-Technology Centers, a science museum professional organization that has grown from a handful of museums at its start in 1973 to more than 200 members.

Support for museum educational materials development and teacher training projects in cooperation with local school systems has been provided in such varied institutions as the Museum of Science, Boston; the New York Zoological Society; the Capitol Children's Museum in Washington, D.C.; the Franklin Institute Science Museum, Philadelphia; the Maryland Academy of Sciences, Baltimore; the Red Mountain Museum, Birmingham, Alabama; the New Mexico Museum of Natural History; and the Lawrence Hall of Science, Berkeley, California.

In all, the Science and Engineering Education Directorate has made 37 awards totalling $ 8.8 million to science museums during FY 84-86. We expect that museums will continue to be active participants in these activities.

The Directorate for Biological, Behavioral and Social Sciences (BBS) supports science museums in several ways.

Many scientists employed at science museums receive research funding in areas supported by BBS. In FY 1986, over $2.0 million from BBS was provided to support scientific research conducted within science museums throughout the country. For example, the New York Botanical Garden is the lead U.S. institution for the Projecto Flora Amazonica, the major bilateral effort underway to catalog the species of plants in the Amazon basin (joint with Brazil). The Cary Arboretum, an arm of the NY Botanical Garden, is the home institution for a major long term project in the BBS Ecosystems Studies Program, the Hubbard Brook Experimental Forest. This project has made a series of major contributions to such topics as acid precipitation and long-term biological change.

In addition, major support is available in the Biotic Systems and Resources program for outstanding systematic research collections of preserved plants, animals and fossils whose maintenance will conserve an essential scientific resource and enhance their availability to the scientific community. These collections are most frequently housed within museums, both private and affiliated with an academic institution. Since 1972, support for these collections amounts to $43.6 million.

The Anthropology program has also been providing support for the improvement of systematic anthropological research collections, most frequently at museums, that are of outstanding importance and in critical need of restoration; in FY 1986, $735,195 went in support of anthropological collections. Support for the infrastructure in science remains a priority within the directorate. We anticipate that support for science museums and their major systematic research collections will continue as part of that priority in the future and that excellent quality scientific research will continue to be supported through the scientists employed at those institutions.

Question: Many educators at the pre-college level are concerned that while the National Science Foundation provides much information on scientific research to schools, it does not make enough investment in developing better methods for teaching science. What plans does the National Science Foundation have to improve this situation?

Answer: The Foundation has a long record of support for research on the teaching and learning processes. The Directorate for Science and Engineering Education (SEE) supports projects that study the classroom theory and practice of mathematics and science education. The Directorate for Biological, Behavioral and Social Sciences supports more basic research related to learning and developmental theory.

In addition, much of the support in SEE for technology and materials development is directly concerned with improving the methodology of classroom practice. Recently for example, we held a special joint meeting with the Carnegie Corporation to encourage increased exploration of the use of video illustration as a routine instructional tool. SEE also places considerable emphasis on effective science teaching through its teacher preparation and enhancement activities. Successful projects in preservice teacher preparation must include instruction in new pedagogical strategies based on educational research. Similarly, summer and academic year inservice workshops for practicing teachers typically stress both recent developments in science and technology and effective methods for communicating this information and raising student interest and motivation. One way of assuring that this happens is through the involvement of teachers and science education faculty in the planning and implementation of such projects.

We believe that this balanced investment -- basic learning studies, applied instructional strategy and classroom methodology -- comprises a coherent and productive research pattern.

Question: There is an overwhelming need among classroom teachers for teacher institutes and training. Projected funding for this area is still well below the 1982-1983 levels. I am interested in what innovative and creative approaches the National Science Foundation might take to reach larger numbers of teachers on what continues to be a very limited budget.

Answer: Many teachers could profit from workshops, courses, and institutes addressing science and mathematics content and pedagogy. The Foundation believes it can have greatest impact through focus on projects that have leverage and impact beyond the initial investment. Therefore, in program announcements, proposal reviews, and project negotiations, special emphasis is placed on dissemination activities in which leadership teachers, who have been participants in NSF-funded projects, serve as mentors to their colleagues. For example, while 6,000 teachers were directly involved in Teacher Enhancement projects in 1986,

we estimate that another 100,000 teachers were secondarily served through a variety of outreach mechanisms. Two projects that have developed especially effective cadres of teachers trained to teach teachers are the National Science Leadership Program of the Woodrow Wilson National Fellowship Foundation and the Honors Workshop for Physics Teacher Resource Agents administered by the American Association of Physics Teachers.

Foundation support for teacher enhancement activities has increased significantly over earlier funding levels. In FY 1980, $10 million was provided for teacher improvement projects. This dropped to $800,000 in FY 1982, and has risen since then to $15 million for precollege teacher improvement in FY 1983, and to the $22.3 request for precollege teacher enhancement in FY 1988.

The CHAIRMAN. Thank you very much.

Let me have you focus for a moment on the connection between science and engineering and economic growth. We recognize the need for university, industry and government cooperation. Could you elaborate a little bit about what programs the NSF has which address these partnerships?

Mr. BLOCH. Yes.

The CHAIRMAN. First of all, how important are math, science, and engineering for our own economic growth? Would you talk about that for a moment and then tell us a little bit about what the NSF is doing to try to bring together industry and Government cooperation in universities?

Mr. BLOCH. I will be glad to address both of your questions. First of all, how important is science and engineering with regard to economic competitiveness? It is very important. I give you, as one particular example of proof, that if one goes back over the last 30 years, so, we will find that about 40 percent of all of our productivity improvements that we made in this country came from new knowledge, from new technology, be it science, or be it engineering. The two are obviously very close together and many times intermix and overlap.

In addition to that, if you look at the world marketplace where some of our competitors are making their big inroads and big impacts, it is in the new science areas or in the products derived from new science, consumer products, just as an example.

I think it is very important that we keep at the forefront of new materials, biology, many of the engineering disciplines, and so forth.

It is also very important that industry, Government, and academia work together. That goes to the second half of your question. Obviously, the generation of new knowledge will not do us any good if it is not being translated into products in the marketplace. There is one way of transferring that knowledge from where it is being generated to where it can be used, and that is by people working together—scientists and engineers from industry working with their academic counterparts, and vice versa.

The Foundation has taken that very, very seriously. The Engineering Research Centers, for instance, and the proposed science and technology centers are geared to making that relationship work. The definition of the centers and the working of the centers, should be highly influenced and determined by industry in the formulation of the problems as well as in the implementation of the research and the performance of research itself. This can be done in terms of dollar contributions and also can be done in terms of people working together in laboratories, equipment being shared, and so forth. So, many of our programs are geared to making that connection a much tighter one than it has been in the past.

The CHAIRMAN. I am sure you're familiar with the article in the Washington Post which stated that a survey released by National Science Teachers Association shows that 7,100 of the nation's 16,000 high schools offer no physics courses, 4,200 offer no chemistry courses, and 1,900 offer no courses in biology.

In light of this, what is the rationale for a less than 10 percent increase in NSF pre-college science and engineering education program, while the overall NSF budget increases by 16.5 percent?

Mr. BLOCH. I mentioned that in my prepared remarks in an indirect way. Our problem is very simple, Mr. Chairman. Our problem is that we are responsible for the whole pipeline, pre-college education, undergraduate education, and graduate education. It is really a question of finding enough resources to have a critical mass for this whole range of problems and the whole range of the pipeline.

We started an undergraduate program in 1987. We are increasing it significantly. As a consequence, the 10 percent that we are adding to the pre-college area is about what we can afford under the 17 percent increase that we have today. So it is not that it didn't get an increase. It got a 10 percent increase. It is just a question of prioritization and balancing between these various different aspects of the problem.

The CHAIRMAN. How do you interact with the Department of Education in terms of furthering the goals of science education?

Mr. BLOCH. Our interaction is on a programmatic level at times. For instance, we are sharing with the Department of Education the funding for a new television program called "Square One," which is a mathematics program. We are funding jointly together with them a program that has been in existence for some years now, namely, "3-2-1 Contact."

Another is obviously being aware of what they are doing and what we are doing so that we don't have any unproductive overlap. That's the second way we are working close together. The third way is that we have day-to-day contact at a programmatic level with the Department.

The CHAIRMAN. Do you have any programs that are targeted to very early education, science education prior to even kindergarten? Wouldn't that make sense?

Mr. BLOCH. It probably would make sense, yes. Do we have any? I would say probably the one that comes closest to it would be "3-2-1 Contact" and "Square One." They are aimed at the elementary grades.

Dr. MOORE. One might add the science museums we support also.

The CHAIRMAN. We spend about $240 billion a year on all forms of education and training programs, both public and private, and yet we spend virtually nothing on the children under 6. As someone who is interested in education and strengthening our education system I wonder whether we ought to be looking more at this early stage and the triggering of childrens' interests. I know that maintaining students' interests is a difficult task even beginning at kindergarten, but I have been interested in and fascinated by this issue of pre-kindergarten education.

You, in the Foundation, have been in the forefront of the interdisciplinary research in biotechnology, a combination of biology and engineering. The potential to map the human genome holds great promise for improving our medical knowledge and understanding of basic biology.

What is the Foundation's role in this mapping effort? What are the mechanisms for coordinating with the other Federal agencies

which are involved? Does this the coordination require more attention?

Mr. BLOCH. Well, obviously our role is manyfold. First of all, we are funding part of that research that is ongoing. Secondly, we are part of a working group on biotechnology which, is chaired by the NSF Assistant Director for Biological, Behavioral and Social Sciences. That working group, on biotechnology, has been charged with the development of a Federal strategic plan with regard to this particular project. They are working on that.

Also we are obviously a supporter of the research that is going on. We are supporting roughly about $15 million a year in that general area, not specifically through the human genome project, but in that general area. Obviously, NIH is a big factor in that area in terms of total Federal dollars, as it should be. So we have a very important role to play. We have been focusing on instrumentation, by the way.

The CHAIRMAN. Mr. Bloch, I have about three or four minutes left for my vote. I will have Senator Stafford start on his questions. I have a few more questions, but for now we will recess.

[Recess.]

Senator STAFFORD. The Committee will come to order.

Senator Kennedy will be back here as soon as he can vote and return. Meantime, Mr. Bloch, let me ask you where would you like the National Science Foundation to be in the next five years? Sounds like an essay question.

Mr. BLOCH. It is a very good question, Senator.

Obviously, where we want to be is at the level of funding that makes possible things that we have not been able to do. We are asking for a doubling of the Foundation's budget over those five years. I would hope that if that happens that we can really make a major impact on the education areas, all areas, pre-college, undergraduate, which we are just starting in '87, and improve our graduate education area and attract more graduate students, U.S. citizens, into the Ph.D. track.

The second area is that we want to have a much broader base of multidisciplinary research than we have today. And the third area that we need to continually upgrade, because these are fast moving fields, are some of the disciplines and facilities that we are responsible for.

Many of the problems we are seeing today, insufficient instrumentation in colleges and universities, facility problems, not enough faculty, and so forth, cannot be solved in entirety, but we would like to see major progress made in those areas.

Senator STAFFORD. When I noticed that the Administration had announced its commitment to double the budget over the next five years for National Science Foundation, I will observe, not entirely seriously, that I wish I could have been at OMB when that announcement was made to Jim Miller, and I'll bet he choked when he saw it.

The Foundation's Engineering Research Center program is now in its third year. Now, what, Mr. Bloch, are the goals of this program? What areas of research are these centers focusing on? Has the engineering research center program been able to attract significant industry participation?

Mr. BLOCH. That's right. This program has been in existence for three years now. We have 13 centers that have been funded to date, 13 and-a-half to be exact. I'll explain the half in a minute.

Of these, they are in many different fields: robotics, telecommunications systems research, biotechnology, structure design and structure research. Waste disposal research is a new center that we are just opening. These centers have attracted a large amount of industry support.

In fact, when we took a look at the year in 1986, the dollars the Government put in were matched by dollars that either the state or industry put into these centers. We have a 50-50 kind of a effort. More importantly, they have attracted a lot of companies that have participated in terms of people participation and also in equipment donations.

I think they really answered the requirements of the time. And they have, by the way, attracted both large and small companies. It is not only large companies that are attracted by it, but very small companies, two or three people companies, that see that they can get something out of those particular centers. And we would hope that would also be the case in the science and technology centers.

Senator STAFFORD. Mr. Bloch, I am pleased to note the Foundation's support for the Experimental Program to Stimulate Competitive Research (EPSCOR). As I understand this program, it is designed to enhance the abilities of selected states to strengthen the state's academic research and development capacities.

What's the status of this program and how does it fit into the Foundation's overall efforts to broaden participation of under represented groups in its research programs?

Mr. BLOCH. It is a very important program. And as you know, we have a large number of new states that participate in that program. One of the states is Vermont, by the way I should mention.

Senator STAFFORD. I thought you would come to that.

Mr. BLOCH. I would say that the program really has as its objective to raise the level of competence of the science and engineering research base in those states. As you know, the states have to make a heavy commitment, not just the National Science Foundation. We are putting in a million dollars a year. We're expecting the states to put much more than that amount into it.

I think what we have seen so far in the previous group of states that we dealt with, is that have come up to a significant level where today they can use the rest of the Foundation programs in a much more intelligent way than they were able to before. Let me just mention one thing, because you mentioned superconductors before, which is a timely topic.

One of the universities where some of the original work was done on close-to-room-temperature superconductives was one of the universities in one of the states that had an EPSCOR Program, namely the University of Alabama at Huntsville.

Together with some of the work in China, some of the work in Europe, and some of the work in other institutions, that was one of the original universities that measured for the first time the high temperature superconducting phenomenon.

Senator STAFFORD. Mr. Bloch, I am advised that Senator Kennedy has some more questions he would like to address to you that he had not covered previously.

Mr. BLOCH. Sure.

Senator STAFFORD. I have asked what I wanted to ask. So I think this is the point where I might say if there is something you wish to state and you have not up until this point, this would be a good time to do that. When I was a prosecuting attorney, we used to ask some of the witnesses that question. [Laughter.]

Mr. BLOCH. I think all I could do is repeat what I said before.

Senator STAFFORD. We will just stand easy until Senator Kennedy gets back.

And here he is.

The CHAIRMAN. Thank you, Senator Stafford.

I will submit some of my additional questions.

Mr. Bloch, I think, all of us are very impressed with your priorities and your focus on the various research centers and the bringing together of a variety of different disciplines.

We are pleased to see the proposals for increased basic research grants. Senator Stafford knows well the battles over reduction of those grants which took place during previous years. This new focus and attention to research, which I think is enormously useful and helpful, also raises the issue of strengthening our facilities and instrumentation.

These facilities do need a good deal of attention. I think all of us are mindful of the fact that grants ought to be awarded on the basis of peer review. However, many universities and schools are left out of this source for development and as a result they are now disadvantaged in terms of being able to participate in the future. It costs a lot to provide the necessary facilities. I know that there are also important needs in upgrading the state of instrumentation.

We welcome the efforts that you are making with regard to women and minorities. It is a small but essential program. The numbers of women and minorities that are going into colleges have increased. However, the percentage of minorities entering science and engineering has not increased proportionately. And the number of women entering these fields is still quite low.

I will submit some other questions to you, but I think that all of us are impressed with what you are doing.

During my absense, did you comment on whether we ought to consider a two year reauthorization? Was that question raised?

Mr. BLOCH. Senator Stafford mentioned the multi-year authorization, and I would really encourage this Committee to speak to our five year authorization bill.

The CHAIRMAN. It seems to me that with that we can get the real focus and direction of the NSF proposals.

Mr. BLOCH. Right.

The CHAIRMAN. Rather than take more of your time and effort to discuss other areas, I think it is probably——

Mr. BLOCH. Could I just make a comment on your comment before?

The CHAIRMAN. Sure.

Mr. BLOCH. It has to do with the subject that Senator Stafford brought up during your absence, broading participation of institu-

tions, states and individuals. This is a commitment that the National Science Foundation has, as you hinted a minute ago. We really have two roles to fulfill: first of all, to stay at the forefront of the best in science and technology, and secondly, to broaden participation.

Many of our programs are geared to that goal. We have states singled out, including Vermont as I mentioned before, that we are trying to bring up to a more acceptable level of accomplishment in science and engineering research. And we are worried about institutions, undergraduate institutions. We are worried about under represented groups like minorities and women. I consider that within the peer review process we have this dual and double kind of a goal.

The CHAIRMAN. Well, I think that's very helpful. And we will look forward to working with you in the future. We are very grateful.

Mr. BLOCH. Thank you very much.

The CHAIRMAN. We will now turn to our Panel, which will focus on science, engineering, and education, and the NSF programs in this area.

I am very concerned, as I know many of you are, about the erosion we're seeing in our country's science and engineering education. We clearly recognize the role of NSF in science and engineering research, but we can't loose sight of its leadership role in education.

We have Mr. LeRoy Lee. Mr. Lee is the President of the National Science Teachers Association and serves as the Executive Director of the Wisconsin Academy of Science, Arts and Letters, and is Chairman of the Science Department of Madison Metropolitan School District. We look forward to his testimony.

We have Dr. David Marker. Dr. Marker is the President of Cornell College, Mount Vernon, Iowa. He is himself a chemist representing the Associated Colleges of the Midwest, the Great Lakes Colleges Association, Reed College, Connecticut College and Rollins College.

I just left the Floor and Senator Harkin was there. He's going to try to get here. He wanted me to extend to you his warm greetings.

And Dr. Rosenzweig. Dr. Rosenzweig is the President of the Association of American Universities and is also testifying on behalf of the Council of Graduate Schools in the U.S., and the National Association of State Universities and Land-Grant Colleges. Dr. Rosenzweig was the Vice President of Public Affairs at Stanford University. He worked at Stanford for 20 years in a number of teaching and administrative positions, and with the University President's staff. We're delighted to have you here.

STATEMENTS OF LeROY R. LEE, PRESIDENT, NATIONAL SCIENCE TEACHERS ASSOCIATION, WASHINGTON, DC, ACCOMPANIED BY DAVID G. MARKER, PH.D., PRESIDENT, CORNELL COLLEGE, MOUNT VERNON, IA, ACCOMPANIED BY ROBERT M. ROSENZWEIG, PH.D., PRESIDENT, ASSOCIATION OF AMERICAN UNIVERSITIES, WASHINGTON, DC

The CHAIRMAN. Mr. Lee, will you start?

Mr. LEE. Yes.

Mr. Chairman, Members of the Committee, on behalf of the National Science Teachers Association, thank you very much for the opportunity to speak to you about an item we consider to be of great importance.

Written material has been distributed, which we would like entered into the record.

The CHAIRMAN. It will be so included.

Mr. LEE. In view of the amount of time available, I would like to submit a summary of that.

The CHAIRMAN. Yes.

Mr. LEE. The summary will be based on our NSTA position, it is also going to reflect my experience of 27 years as a classroom teacher, plus the travel I've done this last two years to over 20 states to listen to teachers in their Science Teachers Association meetings.

The need for increased attention to science education has been well documented. It is not my intent to go into this at this time. Since 1982, the National Science Foundation, with prodding from Congress, has increasingly responded to these needs.

In June of 1986, the National Science Teachers Association convened a two-day conference on NSF education programs. At this conference we brought together the major leaders in all the National Science Education Association meetings to discuss the National Science Foundation approach.

Then we, in July, brought together the leaders of most of the States Science Teachers' Associations, Science Education Associations. We discussed our recommendations with them, and then the Board of NSTA made some recommendations. And in our written testimony we have eight recommendations and 11 very specific programs and budget recommendations. I'd like to talk about a few of those recommendations at this time.

NSTA commends the present programs, the Science and Engineering Education Directorate. We call, though, for an increased and improved balance of funding at the different educational levels.

You hear quite a bit about the educational levels in terms of college and undergraduate and graduate level. You've heard the term, "pipeline." If I may digress to my personal background a little bit, I'd like to relate something that happened to me when I was in grade school.

I grew up on a farm and there one time I had the ability to stack hay. Now, stacking hay means you take loose hay from the field and put it in the stack for the winter. If you think of a loaf of bread about 20 or 30 feet long and 10 feet high, that was my task one summer. My father was very explicit in teaching me how to do a hay stack to make sure that the cap on the hay stack, the top of that hay stack, was aligned properly to protect the rest of the hay from the water and the winter. It was very important.

So one summer when I was doing this, I was very careful to get the cap correct. And about halfway through the whole, one half of the hay stack just kind of collapsed and spread out on the ground.

My father sat down with me and said, "The cap is important, but unless you have a solid foundation, that cap is not important."

I guess as I look at the role of science education, speaking specifically K through 12, we need that Foundation, a very careful approach to that Foundation. The people that we work with are going to be the citizens of tomorrow. Some of them will become scientists; some of them will become engineers; many of them will become technicians; many of them will become policy makers; and all of them will become voters on science and technology issues.

Our concern then is with this Foundation. In our analysis of the NSF budget, we can see no increase in pre-college of what we would consider significance.

Teacher preparation, the same next year as it was this year. Teacher enhancements, no increase. Networks, no increase. Applications of advanced technologies, no increase. Informal science education, no increase. Instructional materials development, no increase. Research and science and learning, no increase.

There is an increase in the pipeline. There is an increase for high school students to receive more training in science. And there is an increase in program assessment. But in what we would consider the pre-college area, there is little increase.

Another recommendation that we have is that all science education programs at the NSF, including the pipeline, be administered through the science and engineering directorate. In that directorate there is a unique blend of expertise in science and in science education.

The teacher community identifies quite strongly with the SEE group of NSF. When I say teacher community, I am talking about K through 12.

Another recommendation is as strongly as possible we recommend the expansion of in-service programs for teachers and faculty members at all levels. The need for this is well documented. As Ernest Boyer has said, long after we forget the reforms of the 1980's, excellence will come down to a teacher in a classroom with some students. Because of that, we feel there is a lot of work that needs to be done with teachers.

The National Science Foundation's program for teachers have worked in the past, they do work in the present. Again, if I may digress to something of a personal note.

When I graduated from college, I graduated with a weak major in biology, and a weak major in English. My first year of teaching was 9, 10, 11, and 12, English and biology. It was the National Science Foundation that gave me a chance to attend summer institutes to upgrade my professional background. They then allowed me to attend an academic year institute to fulfill my, at least round out my academic subject matter. They then gave me a chance to participate in a research participation program which I consider really strengthen my background.

NSF then has given me subject content background, it has given me professionalism, and has kept me in teaching. There is no question in my mind that without National Science Foundation programs back in the 1960's, I would not be in teaching today.

As I have traveled in states to Science Education Association meetings, I typically ask the audience how many of you were trained by National Science Foundation? And a very high percentage of the people over 40, a very high percentage indicate that they

have had National Science Foundation experience. They are staying and teaching.

In Wisconsin there is an NSF program right now called Chautauqua. I think it is a classic example. There were 90 teachers involved in this program for one year. They are teachers who have not been professionally involved in the state. They are teachers from small schools. They have little relationship with teachers in other schools.

Last Friday, I was at a meeting, a state meeting, in which I asked how many were there. And I would dare say 80 of the 90 attended the state conference for first time.

There is a need for increase in summer institutes. There is a need for working with teachers. There are three groups of teachers that we feel need to have some help, for instance, those that are teaching more than one subject. And that includes most teachers.

The CHAIRMAN. I have been notified that we're probably going to be voting in another 15 or 20 minutes and we might have another vote after that. I would like to make sure we hear from all members of the Panel.

I don't mean to intrude, but maybe you could make your concluding remarks.

Mr. LEE. My concluding remarks would be that there are three groups of teachers. First are those that are lacking or teaching too many subjects and only trained in one. Another group is the group that's never had a science course. That's 51 percent of the elementary teachers that are teaching those K through 6th students. And the other group are those that were trained in the 1960's and never have had an opportunity to be retrained or updated. Thank you very much.

[The prepared statement of Mr. Lee, with attachments, follows:]

TESTIMONY
TO
COMMITTEE ON LABOR AND HUMAN RESOURCES
OF
THE UNITED STATES SENATE

IN REGARD TO

THE 1988 AUTHORIZATION
FOR
SCIENCE AND ENGINEERING EDUCATION
AT
THE NATIONAL SCIENCE FOUNDATION

PRESENTED BY

LeRoy R. Lee
President
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April 9, 1987

LeRoy Lee, President of the National Science Teachers Association, is the Executive Director of the Wisconsin Academy of Sciences, Arts and Letters, Madison, Wisconsin. He is also a biology teacher at James Madison Memorial High School in Madison. His undergraduate degree was from the University of Wisconsin, and included a major in biology and minors in English and German. His graduate degree was from the University of Michigan, where he majored in biology. He has taught biology for 27 years. Mr. Lee has extensive experience in science education, including service as director of NSF and AAAS projects and activities. He has also received numerous awards, including the 1983 Outstanding Science Supervisor Award of the National Science Supervisors Association. He has published articles on science education in several journals and is presently the Publisher of the *Wisconsin Academy Review*.

INTRODUCTION

On February 3, 1987, the Wall Street Journal published an account of what happened when the College of American Pathologists, as a test of the system, sent to 5,000 clinical laboratories throughout the United States identical blood samples containing 262.6 mg/dl of cholesterol. The returned lab reports gave results from a low of 101 mg/dl to a high of 524 mg/dl. Many of the lab test results were off by as much as 20%, and more than half had errors of 5% or more. Were these to have been real tests for real people, the misdiagnoses would have been costly and dangerous.

The College of American Pathologists attempted to find the cause of the errors and discovered several sources: instruments were incorrectly calibrated; lab technicians did not know how to use the instruments correctly; wrong chemicals were selected for the tests; etc.

The Fundamental Problem of Scientific and Technical Illiteracy.

Take the preceding example, and multiply it to include all of the devices and instruments in lab clinics, hospitals, research and development laboratories, agricultural test labs, EPA test labs, and all of the technology of our defense establishment, including that of the proposed Strategic DefenseInitiative. One can easily see a fundamental problem: the lack of basic knowledge of science and technology among the many, many people who must work with the instruments, devices and other components of our technology. These persons, even trained technicians, are simply not adequately prepared for their jobs in science and technology.

Similarly, **all of us are now exposed to a rapidly developing technology with which we must cope individually and as a society. We must make personal decisions and vote and participate as citizens in decisions that require a measure of scientific and technological literacy and we do not have it.**

The foregoing example illustrates what numerous reports on the state of science and mathematics education in the United States have shown (*A Nation at Risk: Educating Americans for the 21st Century*; etc.). We are a nation of scientific and technological illiterates, and our security and competitiveness demand a major effort to assure that the whole of our citizenry, present and future, are provided basic scientific and technological knowledge. These reports show that we have little difficulty preparing enough high quality research scientists for the Nation's needs. That is why essentially all of these studies call for the National Science Foundation to concentrate additional resources on science and engineering education for **non-specialists**, instead of concentrating so heavily on preprofessional and professional education of research scientists and engineers, upon whom abundant resources are already expended.

DEVELOPMENT OF THE SCIENCE EDUCATION POSITION

The Milwaukee Conference on NSF Programs.

During June of 1986 the National Science Teachers Association convened a special two-day conference on NSF education programs. This conference was held in Milwaukee, Wisconsin, and included key persons from several science education organizations. The purpose of the conference was to examine NSF science and engineering programs and to prepare recommendations for the Foundation and for the Congress.

Participants in the conference were chosen for their expertise in various fields of science or science education. Organizations represented included: the Association of Education of Teachers of Science; the Council of Elementary Science International; the National Association of Research in Science Teaching; the Council of State Science Supervisors; the National Science Supervisors Association; the Society of College Science Teachers; the National Association of Geology Teachers; The National Earth Science Teachers Association; the Science for the Handicapped Association; and the National Association of Biology Teachers.

A staff member from the NSF Science and Engineering Education Directorate was invited to describe the Foundation's current educational programs. Other resource persons included the project directors from SRI International who are developing a management and program assessment plan for NSF science and engineering education activities, in response to a Congressional mandate.

Refinement by NSTA and State Chapters: Specific Recommendations.

The recommendations of the Milwaukee conference were refined further during a July 1986 meeting of the NSTA Board of Directors attended by officers of the state chapters and affiliated groups of NSTA.

In the testimony we are presenting today, NSTA makes eightrecommendations for special attention by the Committee on Science and Technology.

1. The NSTA Board of Directors commends the present programs of the Science and Engineering Education Directorate at NSF, but calls for an improved balance of the funding at the different educational levels.

2. The NSTA Board agreed unanimously that ". . . all science education programs at the National Science Foundation, including so-called 'pipeline' programs—those involving persons aspiring to or pursuing preparation for science and engineering careers—(should) be administered through the Science and Engineering Education Directorate of NSF."

It is important to note that NSF's Science and Engineering Education Directorate staff at NSF are extremely well qualified. Most have the PhD in a field of science, mathematics, or engineering, **and** have college or university teaching and research backgrounds. Some SEE staff members have degrees in education and teaching experience at the precollege level. (One in that group is a winner of a Presidential Award for Excellence in Mathematics and Science Teaching.) The disciplinary preparation of SEE staff members is comparable to that of their counterparts in the research directorates of NSF.

As a group the SEE staff combine strong scientific credentials with educational backgrounds appropriate to the mission of the Directorate at all levels of education. But their number is too few and must be increased, especially if NSF's programming at the precollege and undergraduate levels is to be increased.

3. The Board recommends as strongly as possible the expansion and strengthening of inservice programs for teachers and faculty members at all levels. Present summer institute activities should be augmented with academic year institutes. The Chautauqua Short Courses Program should be extended to include college teachers. (This program, now being supported for high school science and mathematics teachers, was designed originally for college faculties. In terms of the numbers of faculty served and the very low cost, it is one of the most cost effective programs NSF has ever implemented.)

4. The Board recommended that there be ". . . small grants for individual teachers and school districts."

There are many instances of innovation and ideas for change and improvement being put forward by individual science, math, or engineering teachers. It is too expensive for NSF to administer a program of small grants ($2,000 to $3,000) to capitalize on such ideas. But, such a program would be feasible if NSF had new funds to make umbrella grants to universities or science education research centers so that they could administer and monitor numerous small grants, perhaps through subcontracts. For example, a university science center might receive a grant of $300,000-$400,000 to select, monitor, and support 100 or so small grants to teachers.

5. NSF should give greater systematic attention to the quality of lower division undergraduate education at both 4-year and 2-year institutions.

It is in the first two years of college thatfuture scientists, mathematicians, and engineers receive most of their basic science and mathematics instruction: in many of the same courses, future teachers learn their science and mathematics, as do persons aspiring to careers in medicine, business, and the liberal arts.

The two-year colleges enroll more than half of all lower division undergraduates in the United States. It is also important to note that more minority students attend 2-year colleges than all other kinds of collegiate institutions combined. It is difficult to understand why the NSF chooses to prohibit faculty in 2-year colleges from competing, **on the basis of merit**, in the College Science Instrumentation Program and in other programs open to four-year colleges, or why there are no instructional development programs suitable for strengthening the 2-year colleges and their faculties. Perhaps it is because two-year colleges, although they send forward large numbers of engineering and science transfer students, are not "research institutions."

6. The Board recommended that NSF provide support for " . . . faculty development in both subject content areas and science teaching areas for the lower division science faculty at 2-year and 4-year colleges."

Presently there is no specific support of any kind for 2-year college faculty, and whatever undergraduate support is available excludes 2-year colleges from eligibility. It is very difficult to understand this bias on the part of the Foundation. We mentioned above that over half of the instruction in collegiate lower division science and mathematics is done in the 2-year colleges. Their transfer programs supply nearly half of the science, mathematics, and engineering baccalaureates offered in the United States. Yet NSF's programs suggest a belief that faculty development, laboratory instrumentation improvement, and curriculum updating have desirable effects only if they are done in 4-year institutions.

7. The NSTA Board recommended that "graduate students inscience education be eligible for NSF gradu "e fellowships."

The Association's concern here is similar tothat in the last item. A graduate student pursuing research on cognition (or intellectual development or pedagogy) in a particular science discipline is eligible for NSF's graduate fellowship competition if he or she is working to satisfy requirements for a degree in psychology, but not eligible if exactly the same research is done to satisfy requirements for an advanced degree in education. The fact that such research is carried out in a graduate school of education by a person whointends to continue such research should not disqualify him or her for eligibility for graduate fellowships.

8. The NSTA Board recommended that NSF support a program of ". . . strong applied research . . . that permeates all levels of K-12 science education [and] focuses on teaching, learning, and utilization."

The Directorate should define science education research to make clear the distinctions between this kind of research and that which is concerned with learning and teaching in general. Such general research, as often conducted by cognitive psychologists, should be supported only if it relates uniquely to science, math, or engineering. Otherwise, the research should be supported in a behavioral science division within the research directorate. Similarly, no applied science or education research should be supported within a research directorate, or, as in the past, SEE funds distributed to such research directorates for that purpose.

THE NSF'S PROPOSED 1988 BUDGET

Let us now examine the budget proposed by NSF for 1988.

NSF Ignores Recommendations of Its Own SEE Advisory Board and Task Force on Undergraduate Science and Engineering Education.

The Administration's proposed budget for NSF in 1988 continues to provide just token support for education in the sciences, mathematics, and engineering, while making repeated assertions of greatly increased activity. Inexplicably, the Foundation is choosing to ignore the extraordinary input received in just the past year from its own highest level advisors regarding its education programming.

The National Science Board Report on Undergraduate Education (March 1986) described the critical needs at the undergraduate level and set forth a coherent plan for NSF leadership and programming activities. That report was explicit and logical in urging that the Science and Engineering Education Directorate (SEE) take full responsibility for designing and managing NSF's undergraduate activities. Indeed, a central feature of Chapter 1 of that report called for an undergraduate administrative structure within the Directorate for Science and Engineering Education—not in the research directorates!

The SEE Advisory Committee expressed recently its strong support for the recommendations of the NSB report, and pointed with great concern to inadequate support by NSF of efforts to improve precollege and undergraduate education in mathematics, engineering, and the sciences. This distinguished group of scientists, engineers, and educational leaders also emphasized the importance of a strong Science and Engineering Education Directorate with programmatic leadership across all levels ofeducation. A copy of Professor Gerald Holton's letter, along with the committee's significant resolutions and actions is enclosed as an appendix to this testimony. Why are the strong recommendations of this Advisory Committee ignored by NSF (including as it does, many of the Nation's leading scientists and science and engineering educators (**Gerald Holton**, Harvard; **James Ebert**, Carnegie; **George Pimentel**, Berkeley; **Mary Budd Rowe**, Florida; **Pat Graham**, Harvard; **David Hamburg**, Carnegie; **Walter Massey**, Chicago; **William Baker**, Bell Labs; **Homer Neal**, Stony Brook; **Paul Saltman**, UCSD; and others)?

The Analysis: Essentially No Increase for Science and Engineering Education.

From an examination of Table I it is readily apparent that increases for SEE's precollege programs are virtually ignored in the FY1988 budget proposal. For example, despite the evidence supporting the need for substantial expansion of inservice precollege teacher enhancement activities, this successfully begun program is slated for a zero increase. Repeated calls for development of new curricular materials and for making better use of the computer in schools receive the same answer: zero increase.

As to the much touted "expansion" of undergraduate educational activities, we do applaud the minor response (relative to need) for SEE that will fund new projects for undergraduate faculty improvement and initiate new programs to meet the needs of women, minorities, and the handicapped. But note the zero increase for the College Science Instrumentation Program and the failure once more to recognize the needs of the 2-year colleges and the universities—despite the top priority accorded this program in the recommendations of the NSB report on undergraduate education.

TABLE I

Science and Engineering Education Directorate of the National Science Foundation (millions)

Education Level*	Program	FY87	FY88	Incr. 88 Over 87
	Teacher Preparation and Enhancement			
PC	Teacher Preparation	5.0	5.0	0.0
PC	Teacher Enhancement	22.3	22.3	0.0
PC	Science and Math Education Networks	2.0	2.0	0.0
PC	Presidential Awards for Excellence in Science and Mathematics Teaching	1.2	1.2	0.0
UG	Faculty Enhancement	—	3.0	3.0
UG	Minority, Women, Handicapped Careers	—	2.5	2.5
	Total	$30.0	$36.0	$5.5
	Materials Development, Research and Informal Science Education			
PC	Applications of Advanced Technologies	5.2	5.2	0.0
PC	Informal Science Education	11.4	11.4	0.0
PC	Instructional Materials Development	9.4	9.4	0.0
PC	Research in Teaching and Learning	3.5	3.5	0.0
	Total	$29.5	$29.5	$0.0
UG	*College Science Instrumentation*	$9.5	$9.5	$0.0
	Research Career Development			
GR	Fellowships	27.3	32.3	5.0
PC	Junior Scholars	—	3.7	3.7
	Total	$27.3	$36.0	$8.7
PC	*Studies and Program Assessment*	2.2	4.0	1.8
	TOTAL SEE	$99.0	$115.0	$16.0

*PC = Precollege UG = Undergraduate GR = Graduate

The Elusive Research Directorate Budget For SEE Activities.

Table II on the following page is even more revealing. Despite our being told that NSF is "doing education" everywhere, what we see in the research directorates are large amounts of funds for projects in two principal categories: (1) the largest amounts are for still more research support, as if research were the answer to every deficiency in the collegiate curriculum and note that there is not a single dollar for new college level science programs for the general student; and, (2) the rest is isolated curriculum development for mathematics and engineering with nothing for the curriculum work in the sciences, or for redevelopment of the laboratory experience, or for any other curricular objective identified in the NSB report. Is this a coherent plan for the improvement of education in engineering, mathematics, or the sciences?

NSF claims that it has increased its commitments in "Education and Human Resources" from $30 M in 1987 to $68 M in 1988. We are left guessing as to the precise definitions of these words, but we suspect that they intend still more support for research, since the amounts are for the most part hidden among the research directorate budgets. We note also that no mechanism exists to provide oversight on the ultimate use of the funds, ie. types of institutions and regions of the country, and educational problems.

Major Conclusions.

We draw two major conclusions from an examination of NSF's FY88 presentation on its education plans:

(1) Precollege programs (the very area where documentation of need is strongest) are being neglected in order to put even larger amounts into the basic research system.

(2) The undergraduate college level programs that are most needed, including those for most students, are being neglected, and the few new initiatives being taken are assigned inappropriately to research directorates where staff lack interest, expertise, or commitment to improve science or engineering education.

Again, the strong recommendations of the National Science Board Report on Undergraduate Education and the unequivocal position of the NSF Science and Engineering Education Directorate Advisory Board are largely ignored or perverted in this proposed budget.

TABLE II

Research Directorates of the National Science Foundation

Undergraduate "Education" Programs Fiscal Year 1988

Activity	NSF Directorate or Program	Budget
Student Research	?	?
Faculty Research and ?	?	?
Research in Undergraduate Institutions	?	10.0
Instruments and Laboratory	?	?
		48.5
Curriculum	Engineering Directorate	5.0
Curriculum	Mathematics Division	2.0
		55.5

ELEVEN SPECIFIC PROGRAM AND BUDGET RECOMMENDATIONS

1. All responsibilities for NSF's educational activities at the precollege and undergraduate levels, including leadership, oversight, program management, and budget authority, should be placed within the Directorate for Science and Engineering Education.

2. Because SEE has only risen to a modest base level of funding since the Congress reinstated it in 1983, SEE's precollege and undergraduate programs should receive significantly greater increases in funding than the basic research directorates in the 1988 budget, and in the succeeding years as NSF contemplates a doubled budget.

3. The amounts requested in FY1988 for undergraduate educational programs in the research directorates should be transferred to the SEE section of the budget.

4. The precollege teacher enhancement allocation for FY1988 should be increased by 50%, raising it from 22.6 million to 34.0 million. (This will only partly make up for the fact that while the SEE budget request has gone from $113 M under the Carter budget of 1981 to $115 in this request, the research budget has almost doubled.)

5. There should be an undergraduate faculty development program concentrating at first on lower division undergraduate faculty of science, math, technology, and engineering. These faculty are responsible for 90% of all college/university level instruction. This program should include 2-year colleges, fouryear colleges, and universities. A FY1988 budget of $5 M would get such a program started, with increases in subsequent years to permit work with upper division faculty. This program should include $2 M for a college level Chautauqua short-courses program.

6. The entire curriculum development program should be located in SEE and its emphasis should be broadened to include courses for those not enrolled as science or engineering majors.

The NSF is proposing $7 M for curriculum development to be administered in the research directorates, apparently limited to only calculus and engineering. Proposed is $2 M for revamping the calculus and another $5 M for curriculum development in engineering. There is absolutely no justification for such activities to be done outside the Science and Engineering Education Directorate, which has the expert staff and the confidence of the academic community to administer them. It is especially important at this time that curriculum or materials development in math, science and engineering at the college level be carefully coordinated across the disciplines, and not be a set of random unrelated activities. They should address not only thepreparation of future scientists and engineers,but also the well documented needs of tomorrow's citizens and voters who though not pursuing technical careers will make many decisions affecting U.S. Science and technology.

7. Eligibility to compete for awards under the College Science Instrumentation should be broadened to allow faculty from all types of institutions to compete, as recommended in the NSB report on undergraduate education.

As now offered, this program is an entitlement program for four-year colleges. It should, like other NSF programs, be based on merit and documented need, without regard to institutional type. Both 2-year colleges and universities should be eligible to compete for funds. The program's mission should also be extended to allow more advanced laboratory developments activities as called for in the NSB report. These changes will require that the funding level be increased by $10M for 1988.

8. The REU (Research Experience for Undergraduates) program should be moved from the research directorates to SEE. Research scientists with support from funding agencies other than NSF could then request support, and the present perception that only research universities and major laboratories are acceptable REU sites would be corrected. Equally important, the SEE staff can provide proper leadership and oversight for this important program. In a textbook example of poor design, the present required minimum of 8 undergraduate students on each of what are highly specialized research projects effectively precludes all but the large research colleges and universities from participating.

9. Graduate fellowship support should be broadened in eligibility to include persons pursuing research in cognition, pedagogy, and intellectual development in mathematics and the sciences. Since the number of such graduate students is small, no additional funds for graduate fellowships would be required.

10. Informal science education appears to be funded at the same level as in 1987; but increased commitments for television programming will reduce the funds available for new starts in other areas, thus actually cutting their program support levels. There is a continual need for programs in informal science education at museums, science centers, and on public television. This program should have funds increased by $3 M to permit a better balance among its project types.

11. Programs to encourage women, minorities, and the handicapped should be brought back into SEE where they can beproperly administered, and where some measure of tracking and accountability is assured. The present cross-directorate system allows for questionable accounting schemes relative to women, minorities, and the handicapped, and the focus is almost entirely on programs to produce research scientists and engineers, with no attempt to assure greater opportunity of entry into this pipeline or into related careers.

CONCLUDING COMMENTS

The recommendations of the National Science Teachers Association given here are grounded on a genuine concern for the health of U.S. scientific research and for our national security and competitiveness. The science and engineering research communities interests are ill-served by the narrow view that limits NSF support to research grants and ignores the early (precollege and college) educational system that prepares both future scientists and the rest of society for a technological world. The NSF and its policy making body, the National Science Board, must recognize their responsibility to take a longer view and nurture the system that feeds the pipeline **and** prepares the rest of society for its place in a scientific and technological world.

The importance of the precollege effort is especially significant for the science and engineering research "pipeline" when one considers the following facts: from 1980 until 1992, the 18-24 year old population in the U. S. will have declined by 25 percent, drastically cutting the enrollments of that age group in colleges and universities. While this drop has been occurring, graduate enrollments have held steady mainly because of the huge influx of foreign nationals into our graduate science and engineering programs. Some science and engineering programs are more than half filled by foreign nationals, and already, more than half of all engineering faculty are foreign nationals. **The NSF probably spends more through research assistantships to foreign national graduate students than the entire SEE budget**. We must stimulate our own precollege system if the pipeline of U.S. students is not to be obscured by foreign nationals. The implications for defense and competitiveness are quite obvious.

In justifying minimal support for pre-college science education, Mr. Bloch argues incorrectly that a government agency with only a $1.8 billion budget cannot leverage a $250 billion enterprise like public education. But the science education component of that public education budget is only about $10 billion, and it is only the legitimate federal responsibilitythat is being urged upon the NSF. Consider a similar situation in the national research effort. When all forms of research, from NIH, DOE, DOD, and industrial research, as well as NSF, are taken into account, this effort is a $300 billion enterprise. How, using Mr. Bloch's logic, can a $1.8 billion NSF effort leverage this $300 billion activity? Both arguments are, of course, fallacious. In the case of the research budget, only about $9billion is for basic research, so that a $1.8 billion research budget at NSF is very important. A similar budget at NSF for science and engineering education is just as important to ournation. It is time that the NSF recognize and act upon its **dual** mandate: "Scientific Research and Science Education **at all levels**.

The CHAIRMAN. Okay. Dr. Marker.

Dr. MARKER. Thank you, Mr. Chairman and Senator Stafford.

I am pleased to have been invited to testify before this Committee as you consider fiscal year 1988 authorization for the National Science Foundation.

The National Science Foundation mandate is a dual one: to support the most promising basic research and to provide for our future scientific capacity through the support of science education at the graduate, undergraduate, and pre-college levels. Both our national security and our economic preeminence rest on continued excellence in scientific research and in the commitment of an adequate number of scientists, teachers of science, and technicians for the future.

Projections from the Foundation and from the National Science Board Task Committee Report on Undergraduate Science and Engineering Education, often called the "Neal Report" after Homer Neal, strongly suggest that as we move into the decade of the 1990's we will not have adequate numbers.

We endorse the recommendation of the Neal Report of March 1986 on action to be taken to increase NSF funding for undergraduate science education by no less than $100 million by fiscal 1989.

A renewed and much enhanced emphasis on undergraduate science education is very important because scientific careers are frequently confirmed or abandoned during the undergraduate years.

Early mentors influence the lives of the aspiring scientists in these years and make indelible impressions. Very often they inspire students to enter a specific field of scientific research and/or the teaching of science. In the finest educational programs, even at the undergraduate level, science is best learned by doing science.

At our colleges, many students have the opportunity to work with a Ph.D. research scientist-teacher in a research laboratory in which real science is being done. The insights into scientific enterprise which result are far more realistic than those produced solely through the use of textbooks or sample problems or cookbook experiments. It is not uncommon for our students to go to graduate and professional schools with firsthand knowledge of what it really means to do science derived from participation in every phase of scientific work from research design to the publication of the results in refereed scientific journals.

We are grateful then that the projected NSF budget for fiscal 1988 gives indication of support for undergraduate science.

However, we find the NSF fiscal 1988 budget presented to the public to be somewhat confusing in its presentation of programs for undergraduate science and undergraduate science education.

I must confess that in the written testimony submitted by Mr. Bloch today there has been some clarification, but certainly there is still a lack of clarity.

In Appendix A of our written testimony, we summarize this budget request as we have understood it, which proposes nearly $70 million for activities in this critical education segment, but provides scant and sometimes confusing or overlapping details.

We certainly don't quarrel with the request, if it is a stage in attaining the $100 million of new funds for undergraduate science education in the Neal report, but we feel that we need help in iden-

tifying and understanding the programs to be funded in this budget. It would be very helpful if you would specify line items instead of the information provided in the budget narrative.

Despite the lack of clarity in the proposed budget, the initiatives already taken point us in the right direction. We are very grateful for the earlier action of the Congress in supporting the acquisition of scientific equipment for our laboratories and classrooms.

Congress has recently increased the support for the College Science Instrumentation Program, but that program is level funded for fiscal 1988. Surely we have not reached an optimal target for funding of undergraduate instructional instrumentation with only $9.5 million. This is a sum far below the equivalent $8.9 million in the prototype program in 1964.

The NSF budget summary for fiscal 1988 lists instrumentation and laboratory instruction as one of the, quote, "new and expanded activities," end quote, proposed for the support of undergraduate science education.

But CSIP, the College Scientist Instrumentation Program is neither new nor is it expanded in this budget request. Are there other NSF-wide equipment programs being alluded to here? If so, we need to know which ones and to be informed of the funding levels. Furthermore, if two year colleges are to be included among the eligible institutions for CSIP support, as they should be, then funding should be increasing even more rapidly now than before.

We are pleased by NSF's request for curricular initiatives in calculus and engineering education. We don't understand the logic of locating these initiatives in the research directorates. Undergraduate curriculum proposals should be reviewed by those specialists in undergraduate education. In addition, we see a clear need to extend curricular development to other areas. For example, our introductory science curricula are in crisis. Some entry level science courses serve not so much to introduce students to science, but to select them out, especially for many women and minority students.

Some students, we admit, enter these courses ill-equipped to handle quantitative material. But this really should be no excuse. When students enter college without developing writing skills, we devote ourselves to instructing them in such skills to bring them to acceptable levels. But in the science and mathematics sequence, we often content ourselves with discovering the talented and frightening off the others. A broader approach to curricular development would assist us in this present concern.

The keynote we want to strike in urging new programs and reviving old ones is this: we prefer those which allow choice, choice of venue in research centers, on our own home laboratories, choice of projects, choice of mentoring styles, choice of team size. We are pleased to submit to competition and to subject our proposals to the most stringent criteria of excellence, but we cannot feel comfortable about programs which seem to design out our proven ways of doing science.

In summary then, our requests are these: we urge you to respond to the widely recognized need for support of undergraduate science education. We urge you to set specifics in NSF's budget request for undergraduate science education. Such specifics would be very helpful to us. And thirdly, we request that you authorize 50 million

new dollars for undergraduate science education as recommended in the Neal Report.

Thank you so much for the opportunity to speak on a subject so important to us. We are confident you will find ways to a structure the future health of this necessary component of the nation's science effort.

[The prepared statement of Dr. Marker follows:]

Statement by

David G. Marker
President, Cornell College

on behalf of

The Associated Colleges of the Midwest,
The Great Lakes Colleges Association,
Connecticut College, Reed College and Rollins College

on the

Fiscal Year 1988 Authorization for the National Science Foundation

before the

Committee on Labor and Human Resources
U.S. Senate

on

April 9, 1987
SD-430 Dirksen Senate Office Building

Thank you Senator Harkin, Mr. Chairman and Members of the Committee:

I am David Marker, President of Cornell College of Iowa. I am pleased to have been invited to testify before this Committee as you consider the fiscal year 1988 authorization for the National Science Foundation. In appearing here today, I am representing the twenty-five undergraduate liberal arts colleges which comprise the Associated Colleges of the Midwest (ACM) and the Great Lakes Colleges Association (GLCA)[1/]. Reed College in Oregon, Connecticut College and Rollins College in Florida also join in supporting our position.

The National Science Foundation's historic mandate is a dual one: to support the most promising basic research and to provide for our future scientific capacity through the support of science education at the graduate, undergraduate and pre-college levels. Both our national security and our economic preeminence rest on continued excellence in scientific research and in the development of an adequate number of scientists, teachers of science and technicians for the future. Projections from the National Science Board Task Committee Report on Undergraduate Science and Engineering Education (often called the "Neal Report" after Homer Neal, the committee's chairman)[2/] strongly suggest that as we move into the decade of the Nineties we will not have adequate numbers. After serious and dangerous neglect, the National Science Foundation under Director Erich Bloch has renewed its commitment to the undergraduate component of its mission by increasing the dollars allocated to Research in Undergraduate Institutions (RUI) and instituting very recently the Research Experiences for Undergraduates (REU) program. We are grateful that the projected NSF budget for fiscal 1988 gives some indication of other support for undergraduate science.

1/Neal, Homer A., for the National Science Board, Undergraduate Science, Mathematics and Engineering Education: Role for the National Science Foundation and Recommendations for Action by Other Sectors to Strengthen Collegiate Education and Pursue Excellence in the Next Generation of U.S. Leadership in Science and Technology (Washington, D.C.: Government Printing Office, March, 1986).

2/The members of GLCA are DePauw, Earlham and Wabash in Indiana; Albion, Hope and Kalamazoo in Michigan; and Antioch, Denison, Kenyon, Oberlin, Ohio Wesleyan and the College of Wooster in Ohio. Members of ACM include Colorado College; Knox, Lake Forest and Monmouth in Illinois; Coe, Cornell and Grinnell in Iowa; Carleton, Macalester and St. Olaf in Minnesota; and Beloit, Lawrence and Ripon in Wisconsin.

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We endorse the recommendations of the "Neal Report" of March, 1986, on action to be taken to increase NSF funding for undergraduate science education by no less than $100.0 million by fiscal 1989. (The Neal Report refers throughout to undergraduate science education.) Dr. Neal has testified that the levels were set in an atmosphere of fiscal restraint not in the present expansive climate.

Let us clearly designate that two different kinds of support are under discussion here: 1) Undergraduate science, which includes the Research in Undergraduate Institutions (RUI) program, enabling scientists in non-PhD.-granting departments to compete for research support, and [Small College Faculty] Research Opportunity Awards (ROA), providing regular NSF research grantees supplements to support undergraduate faculty research associates, most appropriately belongs in the research directorates where the goal is a broader base for the research effort. 2) Undergraduate Science Education, where the purpose of the programs is the improvement of science instruction, requires administration and review by experts in undergraduate science teaching. A symbiotic relationship may exist between teaching and research but the program goal should determine the necessary expertise for supervision and review.

The NSF fiscal 1988 budget presented to the public we find very confusing in its presentation of programs for Undergraduate Science and Undergraduate Science Education. In Appendix A we summarize this budget request, which proposes "nearly $70.0 million for activities in this critical education segment [undergraduate]" but provides scant and sometimes confusing or overlapping details to flesh out the request. We do not quarrel with this request if it is a stage in attaining for fiscal 1989 the $100.0 million in new funds recommended for undergraduate science education in the Neal Report. But we feel that we need help, as does the Congress we suspect, in locating and understanding the programs to be funded in this budget. We are asking for better advertising of programs and reporting of program results. We hope you will specify line items instead of the vague information provided in the budget narrative. We also need help in assessing the impact of both new and old programs on the various science communities, included our own, that look to NSF for support.

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In particular we are watching the administration of RUI, REU and ROA to assure ourselves that proposals from our institutions are fairly handled both in the drawing of program guidelines and in the review of submissions. All of us could follow these programs better if the annual NSF publication Grants and Awards were restored.

The good intentions of Congress and the Foundation to support science and undergraduate institutions must be translated into administrative practices that assure that programs and guidelines designed to funnel support to undergraduate projects succeed in this aim. Reporting procedures and other measures to increase accountability will also increase trust between the NSF and the undergraduate science community, trust that the intended funding is finding its way to its designated recipients.

A renewed and much enhanced emphasis on undergraduate science education is so important because scientific careers are frequently confirmed or abandoned during the undergraduate years. Early mentors influence the lives of aspiring scientists in these years and make indelible impressions; very often they inspire students to enter a specific field of scientific research and/or the teaching of science. In the finest educational programs -- even at the undergraduate level -- science is best learned by doing science. At our colleges many students have the opportunity to work with a Ph.D. research scientist-teacher in a research laboratory in which "real" science is being done. The insights into the scientific enterprise which result are far more realistic than those produced solely through the use of textbooks, sample problems and "cookbook" (contrived) experiments. It is not uncommon for our students to go to graduate and professional schools with first-hand knowledge of what it really means to do science derived from participation in every phase of scientific work from research design to the publication of the results in refereed scientific journals.

We are very pleased that Director Bloch has already planned to act upon the recommendation of his Science and Engineering Education Advisory Committee to set up an Office of Undergraduate Education within the SEE Directorate. We hope that the mandate for this office will be very clear and detailed and that it will be

responsible not only for the coordination but also the administration and oversight of all undergraduate programs with the goal of undergraduate educational improvement. We believe it should also have its own advisory committee of specialists in undergraduate education from the major sectors responsible for undergraduate education, including independent liberal arts colleges, two-year colleges, non-Ph.D.-granting public colleges and, perhaps, research universities. The Office should be the central point of contact within NSF for undergraduate science.

Our Key Priorities for Undergraduate Science Education in NSF:

1. **Balance among the components of science education: precollege, undergraduate and graduate.** The prevailing emphasis within NSF has been upon graduate education, where the objective has rightly been to strengthen the quality of training received by potential scientists and engineers. Now we see a strong revival of interest in precollege science, also important for creating higher levels of scientific literacy in the general population and establishing seed beds for growing the scientists of the future. Nothing that I have said or will say in this testimony should be construed as anything but enthusiasm for all such programs. But undergraduate science education has been the missing link in the chain, especially in the years when it was absent from the agenda of the NSF. At this stage large increases in appropriations are needed for undergraduate programs just to establish the balance. We urge you to continue to think in terms of absolute increases rather than percentage increases since the base levels are so low.

2. **Stronger support for existing programs.** The initiatives already taken point us in the right direction. We were grateful for the early action of Congress in supporting the acquisition of scientific equipment for our laboratories and classrooms. This initiative recognized that our faculty are eager and well-equipped to improve science education by themselves if only their laboratories are also well equipped. Congress has recently increased the support for the College Science Instrumentation Program (CSIP) but CSIP is level funded for fiscal 1988. Surely we have not reached an optimal target for funding of undergraduate instructional instrumentation with

only $9.5 million, far below the equivalent of the $8.9 million its prototype, the ISEP (Instructional Scientific Equipment Program) had in 1964.

The NSF Budget Summary for fiscal 1988 (page four) lists "instrumentation and laboratory instruction" as one of the "new and expanded activities" proposed for the support of undergraduate science education in fiscal 1988. But CSIP is neither new nor expanded in this budget request. Are there other "NSF-wide" equipment programs being alluded to here? If so, we need to know which ones and to be informed of the funding levels. Furthermore, if two-year colleges are to be included among the eligible institutions for CSIP support -- as they should be -- then funding should be increasing even more rapidly now than formerly.

The relatively new program which supports Research in Undergraduate Institutions (RUI) has been our greatest hope for responsiveness by NSF to the research aspirations of our faculty. But this is another program which, we gather, is not slated for a significant increase in funding for fiscal 1988. We are concerned about the lack of emphasis on this program in a year of special promises of increased attention to undergraduate science. One of the avowed purposes of RUI was to wean undergraduate faculty researchers from protected funding to the mainstream programs in the research directorates. We are worried that an opposite effect is emerging: experienced researchers from undergraduate colleges who formerly received regular NSF research grants are choosing (or being directed to) the "sheltered" environment of RUI. If this is happening to a significant degree, the main beneficiaries are the non-undergraduate researchers who will share a larger funding pool in the absence of their undergraduate faculty competitors -- and this was certainly not the group Congress and the NSF intended to assist by the creation of RUI! This trend also suggests that more, not less, RUI funding will be needed as the program matures, and that Congress ought to request that NSF study the effects of the RUI program upon proposal traffic to and from the traditional sources of research support within NSF.

3. New and revived programs to serve the special needs of undergraduate science education. It may be useful to think about the needs of undergraduate science

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education in terms of three constituencies: (1) lower level undergraduates and non-science majors, (2) science majors/potential scientists and (3) science faculty. Of course, fellowship and research programs best serve faculty, research participation programs are designed for the upper level science student and equipment programs assist all. Beginning undergraduates are least served by the NSF undergraduate programs already on track. What these students need most is a variety of curricular initiatives which provides release time and reward to the best of their teachers to develop new courses, materials and approaches for the teaching of science.

We would like to see support for individual faculty members -- not research teams or professional educators -- along the lines of the old NSF College Science Improvement (COSIP, and its successor CAUSE, Comprehensive Assistance to Undergraduate Science Education) and Local Course Improvement (LOCI) programs of the 1970's. LOCI gave individual faculty members small but tangible incentives to revise their own curricula and experiment with new materials without administrative encumbrances. As an encouragement to curricular innovation it was far-reaching, extending to colleges of all types in all corners of the country and reaching students by the shortest route -- through their teachers. An NSF curricular initiative, focused on introductory science but without a preconceived agenda for the direction of innovation, is a proven device for encouraging the proliferation of good ideas in all the disciplines.

We are pleased by NSF's request for support of curricular initiatives in calculus and engineering education. However, we suggest that there is a tried and true structure (LOCI) for carrying out that request and extending this good impulse to other disciplines. We don't understand the logic of locating these initiatives in the research directorates. Undergraduate curriculum proposals should be reviewed by specialists in undergraduate science education.

Our introductory science curricula are in crisis. Some entry-level science courses serve not so much to introduce students to science but to select them out, especially for many women and minority students. Some students, we admit, enter

these courses ill-equipped to handle quantitative material. But this should be no excuse. When students enter college without developed writing skills, we devote ourselves to instructing them in such skills to bring them to acceptable levels. But in the science and mathematics sequences we may content ourselves with "discovering" the talented and frightening off the others. Many students who leave science for other fields are bright and graduate with reasonable records. Our science curricula are likely to serve best those who are competitive, linear in their thinking or respectful of teacher authority, not necessarily those who show creative capabilities in science. Furthermore, beginning classes may be large and impersonal and may not yet have utilized fully the best capabilities of computer technology to individualize instruction and engage the active participation of students in discovery.

Primarily because of our long and positive experience with NSF's now-discontinued Undergraduate Research Participation (URP) program, the expansion and strengthening of undergraduate research participation is a top priority for our colleges. We welcome NSF's endorsement of this concept but are concerned that the specific requirements of the new Research Experiences for Undergraduates (REU) program are unnecessarily restrictive and, therefore, the program is less helpful than it should be.

The REU program puts us in mind of the old Undergraduate Research Participation (URP) program, so beloved to our faculties. But some of the most effective features of URP are not reproduced in REU. Grants in REU are to be awarded to researchers who can assemble groups of at least eight undergraduate collaborators, at least half of whom must come from other institutions. We are concerned that the small science departments at even our best colleges will have difficulty gathering such teams and will not be competitive for awards. As we picture the operation of REU, we imagine our students leaving to join groups at larger universities and losing some of the benefits of the one-on-one mentoring which we credit for our success in producing generations of young scientists. And one other point is too easily overlooked: student research grants at our institutions have always functioned in part as faculty

research grants as well, providing our teachers with assistants and collaborators with whom they produce fine publishable research. The Oberlin Conference studies have revealed that of the approximately 7,000 journal articles in the past five years by 1400 science faculty (at the 48 undergraduate teaching institutions included in the studies) one-third had been co-authored with undergraduates. (See Appendix B.)

We look forward to participating in REU to the extent that turns out to be feasible for us because we approve of the concept. But we will continue to feel some nostalgia for URP, a program tailored to the needs of small departments in small colleges -- but which served undergraduate students at large universities as well.

We also cherished the old Science Faculty Fellowship program when it served undergraduate faculty without easy access to university resources.

The keynote we wish to strike in urging new programs and reviving old ones is this: We prefer those which allow choice -- choice of venue in research centers or our own home laboratories, choice of projects, choice of mentoring styles, choice of team size. We are pleased to submit to competition and to subject our proposals to the most stringent criteria of excellence, but we cannot feel comfortable about programs which seem to design out our characteristic ways of doing science.

The undergraduate constituents of the NSF have suffered from insecurity and neglect. Even when the Science Education Directorate and its undergraduate activities were well-funded and strong during the first two decades of the life of the NSF, scientists from undergraduate institutions could never count on their welcome in the research directorates, regardless of their research credentials. During part of that time education activities were housed on the opposite side of the city from the rest of NSF, out of sight and often out of mind. During that period NSF research program officers often understood little about the philosophy and operations of the Science Education Directorate, sometimes assuming that the main beneficiaries of the Directorate were colleges and professors of education, not scientists like themselves. The final blow was the dissolution of the Directorate early in fiscal 1982

and the total eclipse of support for undergraduate science. The small amount of research funds that found its way to undergraduate institutions had meager effect. The present result of these past events is a degree of mistrust that our permanent interests are secure in this renaissance of attention to undergraduate programs in the NSF. This creates a challenge for Congress and the NSF leadership -- to reassure us and our colleagues of the sincerity and stability of these efforts.

Thank you for this opportunity to speak on a subject so important to us. We hope you will find ways to assure the future health of this necessary component in the nation's science effort. The blueprint provided by the Neal Report should be useful to you in your deliberations.

Appendix A

National Science Foundation Support
for Undergraduate Science, Fiscal Years 1987 and 1988

	Fiscal 1987 Current Plan ($ millions)	Fiscal 1988 NSF Request ($ millions)
Support through Science and Engineering Education Directorate (SEE)		
College Science Instrumentation Program (CSIP)	9.5	9.5
"Faculty development" (New)	0	?
Total in SEE	9.5	?
Support through Research Directorates		
Undergraduate curriculum improvement (New)	0	?
Calculus (New)	0	?
Engineering (New)	0	5.0
Research in Undergraduate Institutions (RUI)*	9.5	?* (see PUI note below)
Research Opportunity Awards (ROA)*	1.5	?* (see PUI note below)
"Cross-Directorate undergraduate activities," including:	9.0	40.0+
Research Experiences for Undergraduates (REU)	(9.0)	?
Undergraduate faculty enhancement (new)	0	?
Laboratory instrumentation and curriculum development (new)	0	?
Total(?) in Research Directorates	20.0	?
GRAND(?) TOTAL	29.5	"almost 70.0"*

*It is not clear whether NSF's total for 1988 includes the RUI or ROA programs, which are mentioned separately in the budget document only as a subset under Predominantly Undergraduate Institutions (PUI) for which NSF requested $50.0 million but without breakout by program category. The broad PUI category encompasses research funding for all institutions that have awarded twenty or fewer Ph.D. degrees in fields supported by NSF in the past two years.

II. Scholarly Activity of the Science Faculty by Discipline :
Journal Articles and Conference Papers,
The 48 Liberal Arts Colleges,
1979-80 through 1983-84

A: Journal Articles

Discipline	Headcount Faculty*	N of Fac. Publish.**	% Publish.	Numbers of Journal Articles: Sole Author	Co-author w/ Faclty	Co-author w/ Student	Co-author w/ Stu & Fac	Total Articles	Articles per Fac.	% Student Co-Author
Biology	551	396	71.9%	555	901	494	193	2,144	5.41	32.1%
Chemistry	561	326	58.2%	229	658	539	202	1,628	4.99	45.5%
Geology	180	132	73.3%	268	265	55	25	613	4.64	13.1%
Mathematics	602	277	46.0%	569	325	32	5	931	3.36	4.0%
Physics	387	192	49.6%	335	487	112	73	1,007	5.24	18.4%
Other Sciences	184	104	56.7%	211	258	122	48	639	6.13	26.6%
Science Totals :	2,465	1,428	57.9%	2,167	2,894	1,353	546	6,961	4.87	27.3%

B: Conference Papers

Discipline	Headcount Faculty*	N of Fac. Publish.**	% Publish.	Numbers of Conference Papers: Sole Author	Co-author w/ Faclty	Co-author w/ Student	Co-author w/ Stu & Fac	Total Papers	Papers per Fac.	% Student Co-Author
Biology	551	347	63.0%	696	395	227	109	1,427	4.11	21.5%
Chemistry	561	202	36.0%	493	227	203	35	959	4.75	24.9%
Geology	180	126	69.8%	296	168	71	13	548	4.36	15.2%
Mathematics	602	225	37.4%	529	95	10	9	643	2.85	2.9%
Physics	387	155	40.2%	212	240	58	68	577	3.72	21.8%
Other Sciences	184	84	45.9%	209	70	26	19	324	3.84	13.9%
Science Totals :	2,465	1,140	46.2%	2,436	1,195	595	252	4,478	3.93	18.9%

* Headcount of persons having held teaching faculty status, 1979-80 through 1983-84
** Headcount of such faculty having published at least one item of the type examined

Source: "Educating America's Scientists: The Role of the Research Colleges," a paper prepared for the Conference on "The Future of Science at Liberal Arts Colleges," [illegible], Ohio, June 8-10, 1985, page 46

II. Scholarly Activity of the Science Faculty by Discipline :
Books and Literature Reviews Published,
The 48 Liberal Arts Colleges,
1979-80 through 1983-84

C: Books Published

Discipline	Headcount Faculty*	N of Fac. Polish.**	% Polish.	Numbers of Books Published: Sole Author	Co-author w/ Faclty	Co-author w/ Studnt	Co-author w/ Stu & Fac	Total Books	Books per Fac.	% Student Co-Author
Biology	551	43	7.7%	21	40	0	0	60	1.42	.0
Chemistry	561	38	6.8%	48	49	0	0	97	2.54	.0
Geology	180	32	17.5%	16	22	1	0	40	1.26	3.4%
Mathematics	602	43	8.0%	40	26	0	4	70	1.46	5.9%
Physics	387	19	5.0%	30	12	0	0	43	2.21	.0
Other Sciences	184	22	11.9%	25	14	3	0	41	1.88	6.7%
Science Totals :	2,465	202	8.2%	180	163	4	4	351	1.74	2.3%

D: Literature Reviews

Discipline	Headcount Faculty*	N of Fac. Polish.**	% Polish.	Numbers of Literature Reviews: Sole Author	Co-author w/ Faclty	Co-author w/ Studnt	Co-author w/ Stu & Fac	Total Reviews	Reviews per Fac.	% Student Co-Author
Biology	551	219	39.7%	555	75	32	20	681	3.11	7.5%
Chemistry	561	116	20.6%	455	32	20	12	518	4.48	6.1%
Geology	180	70	38.7%	246	37	15	3	302	4.33	6.2%
Mathematics	602	177	29.5%	1,056	19	1	3	1,079	6.08	.4%
Physics	387	117	30.3%	497	53	5	2	555	4.74	1.1%
Other Sciences	184	80	43.5%	328	29	54	3	414	5.18	13.9%
Science Totals :	2,465	779	31.6%	3,136	244	127	42	3,549	4.56	4.8%

* Headcount of persons having held teaching faculty status, 1979-80 through 1983-84
** Headcount of such faculty having published at least one item of the type examined

Source: "Educating America's Scientists: The Role of the Research Colleges," a paper prepared for the Conference on "The Future of Science at Liberal Arts Colleges," held at Oberlin College, Oberlin, Ohio, June 9-10, 1985, page 47.

The CHAIRMAN. Thank you very much.

Dr. Rosenzweig?

Dr. ROSENZWEIG. Thank you, Mr. Chairman and Senator Stafford. I appreciate the opportunity to be here today to testify. I am here, I should note, on behalf of the Association of American Universities, the National Association of State Universities and Land-Grant Colleges, and the Council of Graduate Schools.

I too have a statement that has been submitted for the record and I will summarize it and make some brief supplementary remarks, if I may.

I want to start by commending Erich Bloch. He is a refreshing new breeze on the Washington scene. I would say that anybody who can, as he has done, persuade this Administration to commit itself to double a budget for an activity that doesn't fly, float, shoot, or explode has done a feat of legerdemain that is truly awe inspiring. He deserves to be commended for that.

I want to speak to the question of science education from a somewhat different perspective than the two witnesses who have just preceded me.

Let me start by making the observation that if the National Science Foundation budget, if the proposed budget were doubled, if indeed in five years the budget of the National Science Foundation were to be quadrupled rather than doubled, NSF still wouldn't have enough money to do all that needs to be done in scientific research and in science education even within the relatively limited scope of its responsibilities. Never mind the responsibilities of the other Federal agencies that have a charter in this area.

It will always be possible, therefore, to argue persuasively that more should be spent on something and less spent on something else within the scope of the budget that's presented.

In my view, the budget that has been presented this year by the Foundation balances the requirements of a wide range of scientific activities as judiciously as anybody else is likely to do. I don't see any reason to rearrange it at the margins and no good reason to believe that some other arrangement of program funds within that budget would do a better job than the arrangement that the Foundation has presented to you. So I support the budget substantially in its present form.

Now, I'd like to address an aspect of science education that derives from the emphasis, the proper emphasis, I think, that the Foundation has placed on the creation of some new interdisciplinary, multidisciplinary research and technology centers. We support that initiative. There are problems with it. There are reasons to be concerned about it.

The Foundation is moving, I think intelligently, to deal with many of those concerns by asking the National Academy of Sciences to appoint a Committee to advise it on the implementation of that program, on the criteria for the creation of centers in the fields that ought to be emphasized in the center development. All of that is very healthy.

It is also encouraging, and this is the one point which I want to elaborate on, it is also encouraging that the specifications for the centers will include an explicit concern for their educational contribution, their contribution to graduate and undergraduate teaching.

I would argue, and I know that my colleagues in the universities would agree, that every activity that's undertaken in a university ought to contribute to teaching.

There is no justification for undertaking an intellectual activity in an educational institution that doesn't contribute to the teaching mission of the institution.

That point is well understood and broadly accepted in connection with graduate education. It is less well understood I think with respect to undergraduate teaching.

The new centers will, I have no doubt at all, stimulate really excellent new research, and will help train the next generation of scientists to do further research. In point of fact, we know how to do that. And we've demonstrated over the last 40 years that we can do it very well indeed, better than anyone else in the world.

Attention must also be paid to the connection to undergraduate education. And the reason, Mr. Chairman, that needs special attention is that modern research is an increasingly specialized and therefore isolating, intellectually isolating activity. Two physicists in the same department of physics in a major university will be pursuing lines of research in which neither one can understand fully what the other is doing.

That is a recent development in the history of science and in the history of education. And it is a special problem with respect to undergraduate education because while research and the acquisition of knowledge is becoming more specialized and more isolating, the essential requirement of good undergraduate teaching has always been the integration of knowledge. As the scholars become more specialized and more isolated, the task of integration becomes more difficult, and is less likely I believe to be attended to unless it is given the special attention that that kind of shifting of intellectual gears requires.

It requires a lot of thought, it requires time, and requires effort on the part of people who are doing it. I am very much encouraged by the explicit recognition of that fact in the formulation of the center's program up to this point and I hope that that will continue to be a central pre-occupation of the program as it develops.

I think I'll stop there, Mr. Chairman. There are many other points that are covered in my prepared testimony, but that would leave time for questions.

[The prepared statement of Dr. Rosenzweig follows:]

TESTIMONY

PRESENTED BEFORE THE

COMMITTEE ON LABOR AND HUMAN RESOURCES

U.S. SENATE

AUTHORIZATION HEARING ON

NATIONAL SCIENCE FOUNDATION FY 1988 BUDGET PROPOSAL

APRIL 9, 1987

PRESENTED BY

ROBERT M. ROSENZWEIG, PRESIDENT
ASSOCIATION OF AMERICAN UNIVERSITIES

ON BEHALF OF

ASSOCIATION OF AMERICAN UNIVERSITIES

COUNCIL OF GRADUATE SCHOOLS IN THE UNITED STATES

NATIONAL ASSOCIATION OF STATE UNIVERSITIES
AND LAND-GRANT COLLEGES

Mr. Chairman, Members of the Committee:

I appreciate the opportunity to discuss with you the proposed budget of the National Science Foundation. It is, in all important respects, an excellent budget. The NSF request affirms the importance of academic science and engineering and quality education to the nation. It recognizes one inescapable fact: even in these difficult times we must invest adequately in new knowledge and people, our nation's two most valuable resources.

In its totality the NSF budget shows good balance between individual investigator-initiated research, new investment in interdisciplinary research centers and investment in human resources. The FY 1988 proposals and the commitment to double investment in NSF by FY 1992 acknowledge the leadership of this Committee and the Congress as well as that of the Director of the National Science Foundation, Mr. Erich Bloch. The Committee has repeatedly demonstrated its thoughtful concern for the nourishment of U.S. science through, for example, its dedication to the continued vitality of the National Science Foundation (NSF) and the National Institutes of Health (NIH). This dedication not only helps assure the future strength of U.S. science, but plays an important role in ensuring that our country can meet the challenge of leadership in the next decades. Mr. Bloch has brought vigorous public leadership to the Foundation. I should like to take this opportunity to commend him publicly

for a job well done.

We are, of course, especially gratified by the strong affirmation of the priority given to NSF by the FY 1988 budget request and the policy goal of doubling the Foundation's budget by 1992. As requested, my testimony focuses on two particular aspects of the National Science Foundation's program -- (1) the appropriate role of research centers as a strategy or vehicle for meeting directly the needs of U.S. science and indirectly the broader economic and social needs of our society, and (2) the Foundation's proposed investment in science and engineering education programs. To these I should like to add a third issue -- the NSF role in addressing the research facilities deficit of our universities.

Research Centers and Groups

The issue of the appropriate role of interdisciplinary science and technology centers is currently being considered in relation to the more traditional vehicle of federal support for basic research -- the individual investigator grant. Recently Dr. Harold Shapiro, President of the University of Michigan, addressed this matter on behalf of the Association before the House Subcommittee on Science, Research and Technology. I will summarize his principal conclusions and concerns; I believe they merit careful consideration.

1. Increasing the share of the NSF budget devoted to the support of interdisciplinary and/or multidisciplinary research center is -- at the current time -- an appropriate strategy to pursue.

Many useful discoveries in contemporary science are available only through an interdisciplinary approach that would be difficult for an individual investigator to manage. Many fields now require the merging of ideas, results and techniques from separate disciplinary areas in order to fully exploit our scientific potential. Evidence to support this view is already visible in many fields and in these areas NSF efforts can be supportive and helpful rather than distorting and frustrating to both scientist and patron.

The call for interdisciplinary and/or multidisciplinary research is as old as the formation of the scientific disciplines themselves. Specialization has had overwhelming benefits, but it also produced a new need to transcend these boundaries. The current NSF initiative, supported by similar efforts currently in place in many educational and research institutions, is, therefore, part of a long history of concern with respect to this matter.

2. The rate of expansion of NSF funding for research centers should be cautious, retain its flexibility, and be the subject of ongoing evaluation.

In developing new centers, NSF faces several challenges. Our scientific resources (human and physical capital) must be used in the most effective way. Strong team leaders with both vision and disciplinary credibility must be located. NSF must do well the difficult job of providing for sound project management. The Foundation must provide leadership in fashioning a congruence of vision between it and prospective scientific leaders. Selecting areas which can be effectively exploited by research center efforts, and forecasting future scientific developments pose difficult challenges.

For these reasons, we believe that NSF's initiative to expand in relative importance the funding of research centers should be constrained by the following considerations:

(a) The performance of each center should be evaluated at stated intervals over its lifetime. Support for them should be time-limited.

Organizations -- as opposed to individuals -- develop a bureaucratic capacity to sustain their support beyond their useful "lifetime." Greater discipline is required, therefore, in terminating support at the appropriate moment. It would be extremely unfortunate if the Foundation gave up too much of its future flexibility by finding itself permanently "engaged" to a fixed group of centers. We especially need to avoid the trap of assuming that multidisciplinary efforts cannot be evaluated by experts in the component disciplines. We are

pleased to learn, therefore, that the Foundation has enlisted the assistance of the National Academy of Sciences in developing its plans for developing the centers. The Academy's report, expected in June, will be widely read by faculty and administrators alike.

(b) In many fields, this form of organizing research efforts would not be appropriate (i.e. most effective). Careful thought needs to be given to selecting those areas of science which could be best assisted by this form of support. Further, in areas where such research centers would be effective the optimal forms (e.g. extent of industry participation) will vary a great deal. Experimentation with different multidisciplinary approaches should be encouraged.

(c) There is a need to ensure that these research centers play an appropriate role in the education of the next generation of scientists and researchers.

The contemporary American research university is characterized by an unusually fruitful and highly admired joining of the conduct of research and the education and training of new scientists and researchers. It is essential, therefore, that these new research center initiatives indicate and subsequently demonstrate how they will meet their educational responsibilities. We need more focus on the potential synergy of such centers with both undergraduate and graduate education. We talk often of leveraging public research funds by also attracting private funds to such projects, but we often overlook the most important leverage available through the public support of research -- the ability to use that support to enhance science

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and engineering education at undergraduate, graduate and post-graduate levels. More broadly speaking, research centers that do not support the mission and values of the institution within which they operate will not prosper. It is important, therefore, to structure these centers so that faculty loyalties to the university as a coherent interrelated academic community are reinforced rather than undermined. Finally, we commend the Foundation for sustaining the individual investigator-initiated research grant as the dominant means of funding academic science and engineering. Of the total $1.5 billion requested for research activities the core research programs account for more than two-thirds. We vigorously support the Foundation's commitment to providing for expanded investment in its core programs. It would be shortsighted and, I believe, a mistake of major proportions if we were to proceed with the proposed development of new interdisciplinary centers and groups at the expense of our continuing commitment to individual investigator-initiated research. The two forms complement one another. In contemporary academic research each has become essential to our future leadership in science and technology.

To summarize, we support the Foundation's initiatives to foster interdisciplinary science and engineering centers. While the challenges are significant, so also are the needs and opportunities before us. The universities and their national associations stand ready to support and, as appropriate, assist the Foundation and the Congress in developing the new center and group activities.

Science and Engineering Education

Turning to my second topic, I must acknowledge the importance of the Foundation's science and engineering education programs to our entire educational system. The vitality of our research system depends on the strength of our educational enterprise, from the precollege K-12 level and two and four-year undergraduate programs to graduate and post-doctoral programs. In each of these areas, NSF has a unique leadership role to play. While responsiblity for education is shared at the local, state and federal levels, we recognize the need for national leadership in stimulating new approaches to quality education in science, mathematics and technology at all levels of the system. We fully support, therefore, the Foundation's efforts to strengthen each of its science and engineering education activities.

Perhaps no area is more fundamentally important to the future health of our educational system that our elementary and secondary schools. I applaud NSF's efforts to provide leadership in strengthening our schools and our teacher preparation programs through its K-12 precollege activites. I can assure this Committee and the Foundation that the executive heads of the 54 AAU universities are keenly aware of the needs at the precollege level. We enthusiastically support NSF's leadership and creativity in this area. Its commitments to strengthening teacher preparation, improving the use of instructional technology and upgrading schools curricula in science and mathematics are vital national efforts.

At the undergraduate level the Foundation has created new opportunities for research institutions to engage students in sponsored research programs. We support the Foundation's effort to foster, within its research programs, a closer coupling of undergraduate instruction with research. We also recognize the serious needs of undergraduate institutions for NSF support to improve instructional equipment and curricula, especially in rapidly moving fields, such as engineering. Because universities confer a majority of undergraduate degrees awarded each year, we are keenly aware of the pressing need to modernize undergraduate instructional programs in science and engineering. I would cite, for example, the experience of the first two years of operation the NSF College Science Instrumentation Program. In two years the program received more than 2200 proposals; yet only 400 awards could be made. The needs far surpass the available resources. We are pleased to know, therefore, that the budget provides for 350 additional equipment awards next year. In our view NSF should continue to address undergraduate needs and opportunities through its research actitivities as well as through specially designed competitive grant programs, such as the College Science Instrumentation Program.

At the graduate level, the Foundation proposes to add 200 new graduate fellowships per year, and to provide for needed adjustments in the stipend. This is heartily endorsed by the university community. It will, I believe, pay great dividends. I must point out, however, that once again no adjustment is proposed for the cost-of-education allowance which accompanies each fellowship. While the stipend, now $12,300, has been

increased to keep pace with the rising cost of living, the education allowance, which is intended to cover the cost of tuition at institutions selected by NSF fellows remains unchanged at $6,000, well below required levels.

Efforts to attract greater numbers of U.S. citizens, including women and minorities, into doctoral programs in science and engineering must continue. Recent studies suggest that we may now be losing ground in the effort to decrease our dependence on foreign national scientists and engineers. In recent years more than half of our new engineering PhD's have been foreign nationals. A significant and rising proportion of new mathematicians and physicists also are foreign nationals. All of these are disciplines essential to any modern technological society intent on maintaining its competitive posture in the marketplace. Therefore the further strengthening of the NSF Graduate Fellowship program, as well as the planned continuation of Presidential Young Investigator program, are essential and welcome investments.

Research Facilities and Equipment

I turn now to my third topic: the research facilities deficit of our universities. In recent years the Foundation has made significant progress toward addressing one crucial aspect of the research facilities capital deficit in our universities. The Foundation has recognized and accepted partial responsibility for addressing the need for modern research equipment in university laboratories. Only a few years ago the Foundation allocated about five percent of its research funds to equipment. Today NSF

is spending between 18 and 20 percent of its research funds, or more than $250 million, on research equipment. In addition it has provided effective leadership in articulating the problem and mobilizing the research agencies, industry and others in response to it. We congratulate NSF for this leadership and applaud the progress which has been made. The Foundation and other federal research agencies must help to ensure that investigators funded to carry out NSF research programs have the tools required by effective competitors in the international scientific arena.

However, equipment is only a part, and the smaller part, of the research facilities problem. Inadequate laboratory buildings constitute the greater problem. NSF should have at least an equal commitment to the modernization of research laboratories.

During the past twenty years federal investment in university research buildings has declined by 95 percent in real terms. In other words, Federal investment in the construction and modernization of university research laboratories has declined twenty-fold. A technologically healthy economy not only requires us to attract, train and hold sufficient numbers of our most able people in science and engineering careers, it requires that we make the necessary investments in research facilities and equipment. Simply put, universities have a very serious problem of obsolesence. While we still can rightly claim to have the most highly developed university system in the world, we must begin to acknowledge that for more than twenty years we have failed to make the appropriate federal investments in university

research facilities. As a result, despite the considerable investments made by the states and by the institutions themselves, many of our research facilities are now out of date; they have become inhospitable and inefficient homes for modern science.

The research facilities problem has been widely documented and acknowledged. The 1986 report by the White House Science Council Panel on the Health of U.S. Colleges and Universities, for example, concluded that a major catch-up effort is needed. It recommended a ten-year, competitive, matching-grant program in the NSF, funded at $500 million per year. We support that recommendation. We further believe that the problem should not be assigned to the Federal government or the Foundation alone for solution. Similar programs are needed in the National Institutes of Health and the other research agencies. In addition, all Federal funds provided for facilities ought to leverage state and institutional funds. Our experience of the 1960s, when NSF and other agencies last had competitive facilities programs, showed that every federal dollar can leverage additional funds. In fact, the NSF successfully leveraged its previous facilities investments by better than two to one. We believe that earlier experience can be repeated, provided NSF and other research agencies provide leadership by establishing competitive, merit-based facilities programs.

New authorizing legislation is required. We hope, therefore, that this Committee will join with Rep. Robert Roe and his colleagues on the House Committee on Science, Space and Technology, who last week introduced H.R. 1905, the "University

Research Facilities Revitalization Act of 1987", in developing legislation along the lines recommended by the White House Science Council. Earlier this week the members of the AAU unanimously endorsed the general approach of H.R. 1905. We would welcome an opportunity to work with this Committee and others in the Senate in formulating a companion proposal.

Conclusion

Thank you for the opportunity to share these views with you. I will be pleased to respond to your questions.

The CHAIRMAN. Thank you very much.

There is an absolute uniformity in terms of your Panel's recommendations. But it is a very helpful comment.

Let me ask each of you to comment on your reactions to the NSF five year plan for enhancing the quality of science, mathematics, and engineering education that was produced in February of this year.

Maybe we could start with Mr. Lee on the K through 12 education, Dr. Marker on undergraduate education, and Dr. Rosenzweig on graduate education. But we welcome any of your comments on any of the others educational levels.

Mr. LEE. The concept of a five year plan I think is very important.

The CHAIRMAN. Would you bring the mike up a little, Mr. Lee?

Mr. LEE. The concept of a five year plan is extremely important, or certainly beyond the one year plan. We need something that we can look forward to and make some plans for the future. And again, as my only concern was the the pre-college. I would like to see it stronger.

Dr. MARKER. I think as well the five year plan is extremely important. The Neal Report seems to me to have set out some rather specific recommendations about where we ought to go with undergraduate science education in the several years ahead. And we strongly support that report.

Dr. ROSENZWEIG. Nothing of importance happens at a university on a one year basis, except the accumulation of credits for students. And that's an administrative artifact and not a reflection, a real reflection, of what's important at the institution.

What's most damaging to the universities in their teaching and their research missions is uncertainty. Anything that increases the degree of predictability of programs and program support will enhance the abilities of the institution to do their job as it ought to be done. So without commenting on any of the specific details of the plan, the fact that it exists and that it is being taken seriously is a welcome new development.

The CHAIRMAN. Let me just ask you Dr. Rosenzweig, about the decreasing number of American students and the increasing number of foreign students earning Ph.D.'s in the U.S., particularly in engineering.

What can you tell us about that?

Dr. ROSENZWEIG. The reason for that is that there aren't as many American students as there ought to be who want to do Ph.D. work in engineering. No American student that I know or is being crowded out, who wants to do a Ph.D., is being crowded out of a program because a foreign student is taking his place. We need to improve the incentives for our best young people to make that choice. That will require an increase in fellowship funding, which is included in the NSF budget this year and over the next three years, four years. It will require a rearrangement of career incentives.

I think one of the central elements in the picture over the last few years has been that—well, it has always been the case that the choice of an academic career meant that an individual would earn less money than in a comparable industrial career.

It has always been the case, until recently, that by choosing an academic career an individual had the freedom and the opportunity to do the kind of work he or she wanted to do. That has been less true in the last few years as scientific instrumentation and the quality of facilities and university laboratories deteriorated and has improved, on the other hand, in industrial laboratories.

So the career initiative, as well as the economic incentive, has pushed people over into business. And that's not bad by itself, but it has gotten out of balance and we need to pay attention to the other side of the equation.

The CHAIRMAN. Dr. Marker, with regard to getting more people, particularly women and minorities, motivated to study science and engineering, do you have any recommendations?

Dr. MARKER. Indeed I do. The record of the history of our institutions in the motivating students to pursue careers in the science, and to pursue advanced degrees is fairly clear. And it seems to me that one of the most important ways we have done that over the years is undergraduate research participation. It is bringing students together with the scientist-teacher mentor. A recent issue of "Change" magazine contained, I think, a relatively impressive testimony to the ability of teacher-scientists in our institutions, through participation in research especially, to motivate students toward scientific careers.

We have not had the undergraduate research participation support in the last few years. So we're pleased to see that kind of support is proposed again in fiscal '88. And we believe that will address the problem you mention, Mr. Chairman.

The CHAIRMAN. Mr. Lee?

Mr. LEE. Quite a bit of studies have been done that indicates that by age by the fourth grade in school students have already started to separate themselves into those that are going on in science and those that are not. This is especially true as it relates to females minorities. We know that, for instance, in elementary school, 51 percent of the elementary teachers do not have any science beyond high school, but yet females makeup the majority of teachers in the elementary school. They become role models.

A study was done in Madison, Wisconsin very recently, I just read it yesterday in fact, of an attitudal survey of fourth grade students, female fourth grade students. And their attitude toward science was 40 percentile points lower than the male students in fourth grade. They had already started to separate themselves out.

The CHAIRMAN. Very interesting and concerning.

I might submit some other questions for which your responses would be most helpful. Thank you.

Mr. Stafford?

Senator STAFFORD. Thank you, Mr. Chairman. I just have a couple of questions following your very interesting presentations.

Let me ask you, if any of you care to respond, how do you think the United States compares with our trading partners in the education and training of the next generation of scientists, technicians, and engineers?

Mr. Lee, do you want to start?

Mr. LEE. I'll start on that. The only experience I have on that, direct experience, is Japan. The National Science Teachers Associa-

tion has been doing some programs with Japanese science educators over the last year and-a-half.

Our impression and our impression from our Japanese partners is that the science education at the elementary level is exceedingly good in Japan. And they're very proud of it, and they should be.

At the next level up, which would be the equivalent of our high school level, there starts to be a very big separation. They start a very heavy push in training of that stage, a specialization. It is hard to compare our high school to theirs because of that separation.

Senator STAFFORD. Dr. Marker?

Dr. MARKER. The number of students from foreign countries that flood into our graduate schools to take up places there because there are not sufficient numbers of our own students to take those places I think is an eloquent testimony to the fact that we are lacking.

Senator STAFFORD. Dr. Rosenzweig?

Dr. ROSENZWEIG. As Dr. Marker said, what is happening the highest level of training in this country constitutes kind of a market test of the quality.

People want to come here rather than go any place else in order to get that kind of training. At the postdoctoral, at the doctoral level, and to a significant degree at the undergraduate level, at least in many institutions, we do very well indeed. I think as we move farther down the educational scale, we do considerably less well as Dr. Lee has suggested.

Senator STAFFORD. To what extent are our universities experiencing difficulty in loosing faculty to industry? And if they are seriously, loosing faculty to industry, what disciplines in particular are being affected?

Dr. ROSENZWEIG. I think, Senator Stafford, if I may, that is an extremely serious problem in many of the engineering fields, in the business schools, and to a lesser extent, in some of the other professional schools, increasingly I think in fields of clinical medicine perhaps. But it is not clear what can be done about it. I have suggested some things that might be done.

The American Electronics Association has in a very farsighted way started some loan programs for doctoral students in electrical engineering in which the loans will be forgiven if the individuals upon receiving a Ph.D. stay and teach in college teaching rather than go into industry.

That would seem like a program against their own interest, but they are farsighted enough to understand that it is very much in their interest that good people remain in college and university teaching.

Senator STAFFORD. Speaking of against our own interests, I do not draw this conclusion, but the fact that our graduate schools are having so many foreign students and they are going away so well-educated may be part of our problem with competitiveness in these times.

Dr. ROSENZWEIG. Maybe, but for the first 150 years of our history all of our postgraduate education was done abroad. So I suppose you can look at it as returning a favor that we owe.

Senator STAFFORD. Does anybody else wish to comment on the question about loosing faculty to industry?

Dr. Marker, do you have any comments?

Dr. MARKER. I have nothing to add to what Dr. Rosenzweig said.

Senator STAFFORD. No comment.

Mr. Lee?

Mr. LEE. No.

Senator STAFFORD. On behalf of the Full Committee let me express our appreciation to all three of you for coming here this afternoon.

[Additional material supplied for the record follows:]

Statement of

The Engineering Education Task Force of

American Society for Engineering Education
National Society of Professional Engineers
National Association of State Universities and
Land Grant Colleges

on the

National Science Foundation
FY 1988 Budget Request

April 1987

Mr. Chairman:

We appreciate this opportunity to share our views on the National Science Foundation budget for Fiscal Year 1988. This statement is being submitted for the record by the Engineering Education Task Force, a multi-society group working together to address major issues in engineering research and education. Member organizations are the American Society for Engineering Education (ASEE) including its Engineering Deans Council, the National Society of Professional Engineers (NSPE), and the National Association of State Universities and Land Grant Colleges (NASULGC).

ASEE is a membership society of more than 10,000 faculty, as well as schools of engineering and engineering-oriented industries. NSPE is a professional society representing 75,000 professional engineers in industry, private practice, government and education. NASULGC is a higher education association whose member colleges and universities educate more than two million of the nation's students.

The Engineering Education Task Force strongly endorses the proposed FY 1988 budget for the National Science Foundation (NSF). We believe the substantial increases proposed for engineering research and education recognize the vital role of the nation's engineering enterprise in strengthening U.S. economic competitiveness and the quality of life. It is the research achievements and education of young engineers and scientists today that will lead the nation into

the high technology future of the 21st century. Our comments will focus on the education programs within the Foundation.

NSF Education Programs

Continued support for NSF precollege mathematics and science programs is important to the health of engineering and scientific research and education. Highly motivated, well-prepared students must come out of the high school pipeline or the nation will face a serious shortage of the engineering workforce necessary for the increasing needs of government, industry and academe. NSF precollege programs in recent years have helped spur a nationwide effort to improve precollege mathematics and science. They can inspire such efforts as the MATHCOUNTS program sponsored by NSPE in which seventh and eighth grade students receive coaching and participate in mathematics competitions, and the Junior Engineering Technical Society (JETS) sponsored jointly by ASEE and NSPE.

Expansion of graduate programs at NSF forms another key link in strengthening the engineering education system. Expanding the number of graduate fellowships, Presidential Young Investigator (PYI) awards, and engineering research initiation awards will help more institutions attract, keep and develop promising young engineers as graduate students and faculty members. One of the most serious problems facing schools of engineering today is the shortage of faculty: a 1985 ASEE survey showed an 8.8 percent vacancy rate in funded engineering

faculty positions. The figure rises to an alarming 19 percent if one considers restoring the faculty-student ratios of the mid-1960's. There are several reasons for the faculty shortage -- including higher salaries and better research facilities in industry -- but prestigious NSF fellowships and research opportunities offer important incentives for the brightest students to consider academic engineering careers.

The Undergraduate Education Initiative

Of special significance to the engineering community is the Foundation's proposed initiative in undergraduate education. Over the past several years, NSF has maintained strong graduate education programs and since 1983, has considerably upgraded its precollege activities. But since the 1970's, undergraduate education -- the vital bridge between high school and graduate study -- has been sorely neglected at the Foundation. This new undergraduate initiative will begin to redress that unhealthy situation.

Unlike the scientific disciplines where the principal point of entry into the professions is the doctoral degree, more than two-thirds of the nation's new engineers complete their formal education with the baccalaureate degree. This makes it particularly critical that undergraduate engineering education be first-rate; most engineers do not go to graduate school to learn the technological tools and processes of their profession.

Serious Problem Areas

Partly because of its own success and because of increasing government and industry demand for engineers, the engineering education system is under severe strain. Engineering enrollments have doubled over the past 10 years at the same time that engineering schools have been experiencing serious fiscal constraints. In combination with other factors, this strain on resources has led to:

--- serious overcrowding of classrooms with resulting faculty overload, loss of morale and "burnout",

--- a severe shortage of engineering faculty, particularly in such areas as electrical and computer engineering. The ASEE 1985 survey showed an 8.8 percent vacancy rate in funded engineering faculty positions, up from 8.5 percent in 1983,

--- inability to update curricula to reflect rapidly changing technologies and engineering practice,

--- deterioration of laboratory experiences because of obsolete equipment and facilities, along with the rapid pace of change in instrumentation,

--- continuing low numbers of U.S. engineering students going on to graduate study and attainment of the PhD. The ASEE 1985 survey showed that only 59 percent of engineering graduate students were U.S. citizens; the remaining slots were filled by non-citizens,

--- reduced rate of success for engineering schools in attaining a full six year accreditation rating.

These problem areas have been well-documented in such recent reports as the National Science Board's Undergraduate Science, Mathematics and Engineering Education (NSB 86-100) and ASEE's Quality of Engineering Education.

The Role of NSF

NSF cannot be expected to address these problems singlehandedly nor to remedy the situation overnight. But what the Foundation can do is what it does best: demonstrate federal leadership in an area of national importance, serve as a catalyst for the best minds in academia to turn their attention to researching and developing solutions to the problems, and leverage resources from industry, state and local governments and academic institutions in a broadly-based, synergistic effort to address the challenge.

We believe NSF's proposed $68 million program for FY 1988 is an important step in this direction and we applaud the Foundation's foresight and commitment to substantially improving undergraduate engineering and science education.

What Can NSF Do?

Curricula Reexamination. By providing a nationally competitive, merit-based program of support, NSF can inspire major reexamination of engineering curricula including means of incorporating design, synthesis, computer integration and engineering systems into curricula, as well as finding innovative ways of making teaching more effective and efficient. This can include development of new computer softwares, creation of self-paced learning modules or new instructional technologies for face-to-face and learning at a distance.

Laboratory Redevelopment and Instrumentation. In recent years, the engineering laboratory experience for both undergraduate and graduate students has deteriorated. In conjunction with curricular redesign, the laboratory experience must be revitalized. Efforts are needed to find cost-effective ways of providing students with hands-on technical experience, including exposure to contemporary engineering practice and today's technologies.

Faculty Development. A wide variety of NSF-fostered activities could increase the attractiveness of faculty careers and contribute to the lifelong professional development of individual faculty members. The possibilities include new research opportunities not only in technical fields but in engineering teaching and learning, as well as expanded workshops, seminars, sabbatical leaves and faculty networking.

Undergraduate Research. Opportunities for promising undergraduates to experience first-hand the rewards and challenges of academic research could prove a major new incentive for students to continue on to graduate study and academic careers.

Summary

Through the Foundation's leadership, its role as a catalyst for activity, and its ability to leverage resources, we believe these programs will generate a nationwide effort to revitalize undergraduate science and engineering education. This, in turn, will help ensure

the nation sustains the skilled, well-educated and flexible workforce necessary for it to remain competitive in the economic, industrial and national security spheres.

Once again, the Task Force urges you to fully support the FY 1988 budget request of the National Science Foundation. We believe the Foundation's research and education programs -- particularly the undergraduate education initiative -- represent a sound investment that will benefit the nation both now and in the decades to come.

CONSORTIUM of SOCIAL SCIENCE ASSOCIATIONS
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STATEMENT OF THE CONSORTIUM OF SOCIAL SCIENCE ASSOCIATIONS (COSSA)

Howard J. Silver
Associate Director for Government Relations

on the

FY 1988 BUDGET FOR THE NATIONAL SCIENCE FOUNDATION

Prepared for the

COMMITTEE ON LABOR AND HUMAN RESOURCES

U.S. SENATE

The Honorable Edward Kennedy, Chairman

April 20, 1987

American Anthropological Association • American Economic Association • American Historical Association • American Political Science Association
American Psychological Association • American Sociological Association • American Statistical Association
Association of American Geographers • Association of American Law Schools • Linguistic Society of America

The Consortium of Social Science Associations (COSSA) represents more than 185,000 American scientists across the full range of the social and behavioral sciences disciplines. It functions as a bridge between the research world and the Washington community. A list of COSSA Members, Affiliates, and Contributors is attached.

COSSA would like to take this opportunity to express our appreciation to the Committee for its past strong support for social and behavioral science research at the National Science Foundation. What follows are our comments on the proposed FY 1988 budget for the NSF and some of the issues raised by that budget.

We strongly support the proposed overall increase of 16.5% in the FY 1988 budget and the proposed doubling of the Foundation's resources by 1992. In this era of budgetary restraint, the strong commitment of the administration to invest in this nation's scientific endeavors reflects an understanding of the importance of basic research to America's future as a great nation. Reducing that commitment will decrease the nation's ability to compete. We urge the Congress to accept the full increase.

The 16.2% increase for Research and Related Activities is also welcome. We strongly urge the maintenance of that increase during the Committee's deliberations. The 13% increase for the Social and Economic Division and the 12% increase for the behavioral programs of the Behavioral and Neural Sciences Division reflect continued NSF support for these programs. These increases will finally return the social and behavioral science programs to their FY 1980 levels in constant dollars.

While it is long past time for this level to be reached, it is no longer a sufficient goal. In FY 1981 President Carter's last budget for NSF requested $1.15 billion. It included $40 million for social and economic science and $39.5 million for behavioral and neural sciences. In FY 1988 the total NSF budget request is $1.89 billion. Yet the request for social and economic science programs is only $36.0 million and for behavioral science programs is only $25.8 million. Thus, while funding for NSF has increased significantly in the past eight years, the share of those funds going to social and behavioral science research has decreased. COSSA believes that the Subcommittee should increase funding so that 5% of the Research and Related Activities budget goes to social and behavioral science research. This would mean adding $14 million to the FY 1988 proposed funding. We believe this is a justifiable goal given the intellectual vitality and ferment in these sciences and their importance to the nation.

The release later this year of the report of the National Research Council's 10 Year Outlook Study for the social and behavioral sciences will provide a significant picture of the vitality, ferment and contributions of these disciplines. Although not meant to be a comprehensive analysis it will indicate the challenges and opportunities for researchers to develop their work in multi-disciplinary fields and activities. We believe the Committee should pay close attention to this valuable document.

The emphasis on multidisciplinary activity is also reflected in the proposed FY 1988 NSF budget. The inclusion of the social and behavioral sciences in the Foundation's proposal for science and technology centers is appropriate. The proposed National Geographic Information and Analysis Center (NGIAC) will provide greater access to the products of digital remote sensing, geographic information systems, computer cartography, and computer graphics, which will form the basis for major advances in geographical analysis, spatial statistics and expert systems. The enhanced information portrayal and decision making capacities resulting from such theoretical advances will enable society more effectively to resolve the complex environmental and social issues the nation faces now and in the future. This center will involve expertise in disciplines including: geography, information science, computer graphics, political science, remote sensing, risk analysis and many others. Commercial vendors, government agencies, and research universities will share in the services that will be provided by the NGIAC.

The Decision, Risk, and Management Science Program (DRMS) is also strengthening its efforts to encourage collaborative interdisciplinary research across the decision sciences. It too is moving to accept multi-year, multi-investigator proposals for programs of research integrating research strategies and disciplinary perspectives. Three broad problem areas are suggested for exploration: 1) risk perception, communication and management; 2) group decision making; and 3) artificial intelligence approaches to problem structuring and model building for decision support. Here too the number of disciplines involved is large: from artificial intelligence and expert systems to political science, psychology and sociology, to organization design and general systems theory.

In the behavioral sciences a major initiative in the neurobiology of learning and memory will also include increased support for multidisciplinary research teams, and the establishment of a small number of multidisciplinary research and resource centers. Greater elucidation of the neural structures and processes which underlie the phenomena of learning, memory and information utilization will be the goal of this research.

These three initiatives in geography, decision, risk and management science, and psychobiology are significant indications from NSF that the social and behavioral sciences are an important part of the Foundation's agenda for economic competitiveness. Full support of the NSF's budget request will allow these important research initiatives to go forward.

Concern has been raised in many places about NSF's move to encourage the development of science and technology centers, often perceived at the expense of individual investigator initiated research. COSSA is concerned as well. For many of the social and behavioral science disciplines, the individual investigator remains the key to significant basic scientific research. Yet we can agree with Dr. Harold Shapiro, President of the University of Michigan, who has stated that NSF support of centers "is -- at the current time -- an appropriate strategy to pursue." We also agree with his comment that the "rate of expansion of NSF funding for research centers should be cautious, retain its flexibility, and be the subject of ongoing evaluation." The Committee should keep a wary eye on this situation since the long term effects of support for such centers is at the present unknown.

This would be one of the reasons we would continue to support an ongoing role for the authorization committees in their relationship with NSF. Congressional oversight through the authorization process remains an important check on the agencies of the executive branch. In this year when we celebrate the bicentennial of the Constitution, checks and balances should be reinforced. The Committee should resist moving to a five-year authorization for the Foundation.

There are other initiatives for the social and behavioral sciences in the proposed FY 1988 budget that COSSA believes further enhances the necessity to support the proposed increase for NSF. Proposed funding for methodological and research resource development in anthropology will include new emphasis on improving ethnographic research methods and on cross cultural research in this discipline. Analysis of regional databases will provide archaeologists with greater research opportunities.

In political science and economics, increased support for postdoctoral students in political economy will allow for greater study of international economic competitiveness, international trade, and the economic consequences of public sector growth. Continuing support for the three national social science databases -- the Panel Study of Income Dynamics, the General Social Survey, and the National Election Studies -- remains important providing the data necessary to evaluate the nation's

economic, social and political progress. Data collection efforts on Supreme Court decision making should provide students and observers of the court with an important new and comprehensive source of information.

The 16% increase proposed for the Science and Engineering Education Directorate represents a further step in the reinvigoration of that directorate. The commitment of the Foundation to establish a coordinator of undergraduate education is an excellent idea. We also agree with NSF that providing resources for undergraduate education within the disciplines allows for the best integration of research and training for undergraduate social and behavioral scientists. We also applaud the enhanced support for graduate students through increased numbers of fellows and increased stipends that will somewhat mitigate the impact of the Tax Reform Act of 1986.

In the past we have regaled the Committee with lists of significant research accomplishments by social and behavioral science researchers. You have demonstrated time and again your belief that these accomplishments are important to the scientific enterprise within the United States. We ask you to continue that support in the future by giving NSF its full FY 1988 request.

Thank you this opportunity to present our views.

Statement

by

Dr. Sheila E. Widnall

President

American Association for the Advancement of Science

on

The Fiscal Year 1988 National Science Foundation Budget Authorization Request

Submitted to

Committee on Labor and Human Resources

U.S. Senate

April 22, 1987

Biographical Information

Sheila E. Widnall

Sheila E. Widnall (aeronautics, astronautics), 1938; B.S., 1960, M.S., 1961, and Sc.D., 1964, Massachusetts Institute of Technology. With MIT since 1964; professor of aeronautics and astronautics since 1974. Director of university research, U.S. Department of Transportation, 1974-75. Lawrence Sperry Award, American Institute of Aeronautics and Astronautics, 1972; Outstanding Achievement Award, Society of Women Engineers, 1975; member, National Academy of Engineering; Board of Directors, AIAA, 1975-77; Board of Visitors, U.S. Air Force Academy, 1978-84; Executive committee, Division of Fluid Dynamics, American Physical Society, 1979-82; Committee on the Education and Utilization of Engineers, National Research Council, 1981-84. Current Activities: Boards of Directors, Carnegie Corporation and Chemical Fabrics, Inc. (vice Chairman); Panel on Public Affairs, APS; U.S. National Committee on Pure and Applied Mechanics; Committee on Fluid Dynamics, American Society of Mechanical Engineers; Advisory Committee to the Engineering Directorate, National Science Foundation; associate editor, Physics of Fluids, ASME Journal of Applied Mechanics. AAAS activities: Board of Directors and Council, 1982-86; Executive Committee of the Board, 1984-; Committee of Judges, AAAS-Westinghouse Television Award, 1983-; member-at-large of the Section Committee, Section on Engineering, 1984-88. Current President of AAAS.

Introduction

We thank you for the opportunity to express our views on the Fiscal Year 1988 National Science Foundation Budget Authorization Request. I would like to clarify my role in presenting these comments. Although I am a Professor of Aeronautics and Astronautics at MIT, I am submitting these remarks as the President of the American Association for the Advancement of Science -- an organization of 130,000 scientists and engineers and the publisher of the journal Science.

The specific areas addressed in this statement include some overview comments on the budget as a whole; supercomputing and science; mathematics, science and engineering education; instrumentation; and individual vis-a-vis group research awards.

Overview Comments on Budget as a Whole

First, we strongly support the overall growth rate reflected in the budget request. And while it may be optimistic to expect the plan for doubling the NSF budget to the $3.2 billion level by Fiscal Year 1992 to come to fruition, we do support the objective. We acknowledge the difficult set of priority questions facing the Congress in the context of the Gramm-Rudman-Hollings deficit limitations.

However, the proposed rate of growth in the NSF budget is a major, if partial, step in the direction of redressing the problems associated with the level plateau of investment in research from the late 1960s to the late 1970s. While I do not

intend to claim that this national underinvestment in research explains fully the state of our current economic problems domestically and internationally, I think a very strong case can be made that future research investments must be an important part of a total program for revitalizing our economy.

To the extent that we differ from the program and budget proposals of the NSF, it is on priorities in a few areas. I hasten to add that the areas of agreement are large and the areas of differences are relatively small. It is in science and mathematics education areas that we find ourselves in less agreement than in others.

Future of Supercomputing

Turning now to the subject of supercomputing because it is so crucial, I will offer a perspective which stresses the importance of supercomputers in two broad ways: (1) as part of wide-area networks and, (2) as a major influence in the transformation of research in science and engineering.

There is a strong rationale for NSF support of supercomputers in the research world. I consider their role as a major element in support of U.S. science and engineering research. And we strongly support last year's Congressional action in providing for a substantial increase in NSF's supercomputing program.

I strongly support the arguments which have previously been presented to the Congress stressing the vital importance of supercomputing capabilities to the performance of high quality

supercomputing capabilities to the performance of high quality research in an increasing number of fields of science and engineering. And it is important for us to acknowledge the need to look at the acquisition of these capabilities in a national context -- not just through the lens of the National Science Foundation. The Departments of Defense, Energy and Health and Human Services are also involved in significant ways, as is industry. Supercomputing capabilities will be critical to enhancing and facilitating advances in research -- from fundamental science to industrial and governmental applications, including national security.

I would like to underscore the urgent need for increased federal sponsorship and support for a national higher education computer network. More specifically, we must think seriously about establishing supercomputer centers in the context of a national network.

In this respect, during the past year NSF has taken some very positive steps both in supercomputers and in networking. Not the least of these was the reorganization of various computer-related offices at NSF under an Assistant Director for Computer and Information Science and Engineering. Another was to explicitly place in this office the program director for networking.

It goes almost without saying that communication has always been central to the world of research -- for collecting data and providing access to it; for exchanging information; for

conducting meetings, discussions and seminars; for collaborating with widely separated colleagues; and, finally, for disseminating results.

However, increasingly over the past few decades, many observers have noted that the pace and complexity of research, especially collaboration involving different institutions and interdisciplinary areas, have substantially increased scientists' communication needs. Scientists and engineers in many, if not most, fields now need immediate access to data and information, to colleagues and collaborators, and to advanced computing and information services. A major point, made by various observers including D. M. Jennings (former Program Director for Networking, NSF) -- with which I strongly agree -- is that to be really useful, communication and information facilities must be integrated with the researcher's normal day-to-day working environment.

I also strongly agree with the concept of Jennings and his colleagues at the NSF that a scientist should be able to use computing and communications tools by working at an advanced graphics workstation. Via that single window, the scientist may gain access to required computing facilities and databases and communicate with peers, colleagues and researchers all over the world. It is this combination of computing, communications and information sources which we call computer networking. These networks -- when in place -- will provide the structure that combines geographically separated researchers, computing

resources, and information bases into a single integrated environment.

Regrettably, we are not yet at that advanced state. The "bad news" is that, historically, computer network development and applications are best described as fragmented and incomplete. One result has been a bewilderingly wide array of different technologies and a staggering number of incompatibilities. On the "good news" side, however, there are some developments which call for encouragement and support by your Committee. The NSF is focusing increasing attention on just these kinds of problems (the different technologies, formats, and incompatibilities). And very important is a growing focus on the adoption of standard computing networking protocols and on the development of the very complex software so necessary to successful network operations.

A specific element of NSF strategy involves establishing and building a national networking program under the name NSFnet. The concept of NSFnet is not only to build new networks but also to add onto existing networks; it will provide both high-speed access to supercomputers and communication among scientists all over the nation. While NSFnet has been designed initially for supercomputer users to gain access to supercomputers and to communicate with each other, it also is expected eventually to be a general-purpose computer communications network for the entire academic research community and associated industrial researchers. In short, NSFnet seeks to become a "network of networks." This strategic concept draws heaviiy upon the concept

and experience of ARPANET which was established 18 years ago by the Defense Advanced Research Projects Agency.

Looking at all of this through the eyes of some NSF planners and others, it is possible to see the following picture beginning to emerge. An individual researcher will be working at a terminal connected either to a local super-minicomputer or to a graphics work station. These computers will be connected with a local area network (LAN) for local communications and resource sharing. The LAN itself will be connected to other LANs on the campus or nearby research parks. This collection of interconnected LANs will form a campus network. At higher levels, this campus network will be connected, via a campus gateway system, to one or more of the wide-area networks in the NSFnet to provide the researcher with access to the world, including other supercomputers, other researchers, and vast sources of data.

In recent years the National Academies of Sciences and Engineering have been examining how the various fields of science and engineering have been changing. Many of these changes are affecting the directions, content and boundaries of traditional disciplines. I would add that supercomputers are already beginning to have significant transforming effects on the performance of research. These effects undoubtedly will continue to unfold and to have major impacts of the conduct and organization of science and engineering.

As I survey the supercomputer scene and its impacts, I think it is possible to say that quite clearly the United States has retained a leadership position. What is important is that we maintain the momentum which has been developed in recent years.

In concluding this section, I would like to make several summary remarks:

(1) Computers of all kinds, including large supercomputers and mini-supercomputers, are becoming crucial to making new discoveries and are increasingly central to advances in most fields of science and engineering.

(2) There is an immediate need to make supercomputers available to U.S. researchers as widely as possible.

(3) The advanced work station will become an important feature of research performance in the years ahead.

(4) Computer networks are required to link researchers via their workstations to supercomputers, to data bases, and to each other.

(5) The supercomputer programs -- as supported by NSF, Defense, and the Department of Energy -- have acted as a spur and incentive for U.S. industry, in ways comparable to the federal government's support for early large mainframe computer development.

(6) Universities have played an important role not only in scientific and engineering areas related to supercomputers but also have provided a "test bed" service in assisting U.S. industry in the development of new ways to conduct, present and

interpret research carried out on supercomputers. A specfic feature of this "test bed" service is that graduate students trained in university research involved with supercomputers will be an excellent source of trained manpower for industry.

I hope the Committee will give its strong support to NSF's efforts aimed at establishing and building a strong supercomputer program and a national networking program. If supported at adequate levels and managed effectively, NSFnet is likely to have far-reaching, powerful positive effects on the conduct of science and engineering and advancing networking in the United States.

It is worth stressing that advances in supercomputing and networking are potentially among the greatest advantages to be gained in the performance of U.S. science and engineering relative to other parts of the world. Finally, in the industrial sector I should note that a number of leading firms, such as MCI, AT&T and Bell Labs, see networking as a central feature of their strategy for achieving growth and success domestically and internationally in coming decades.

SCIENCE, MATHEMATICS AND ENGINEERING EDUCATION

In contrast to simply addressing budget numbers, we have chosen to present our views on science, mathematics and engineering education in a broader context.

The Scope and Nature of U.S. Education Problems

Others have described and verified the serious state of affairs in U.S. education and underscored the gravity of the associated problems. Numerous special studies and reports cover education generally and science, mathematics and engineering education particularly. To set the stage for the remainder of my remarks, I will provide a few key excerpts which capture several essential ideas.

First, in a recent 1986 report of the Carnegie Forum on Education and the Economy, A Nation Prepared: Teachers for the 21st Century, it was stated that: "The 1980s will be remembered for two developments: the beginning of a sweeping reassessment of the basis of the nation's economic strength and an outpouring of concern for the quality of American education. The connection between these two streams of thought is strong and growing."

Second, in a report to the President of the 1984 White House Conference on Productivity, Productivity Growth: A Better Life for America, it was observed that: "Without a literate, skilled, healthy, and motivated labor force, capital and technology cannot create a productive environment."

Third, in a 1983 report of the National Commission on Excellence in Education, A Nation at Risk, it was argued that: "If only to keep and improve on the slim competitive edge we still retain in world markets, we must dedicate ourselves to the reform of our educational system."

Finally, the Task Force on Education and the Economy,

Education Commission of the States, said in its 1983 report: "It is our judgment that a high general level of education is perhaps the most important key to economic growth."

Clearly, education is increasingly seen, along with international business and trade, as a key area of concern in our search for solutions to the problems we associate with our diminished competitiveness. Perhaps it is no exaggeration, then, to suggest, as has the National Journal, that we have a large "education deficit" as well as a "budget deficit."

Our "education deficit" is across the board -- in teachers and teacher training, in learning methods, in educational motivation, in school organization, in curriculum content and structure, and in educational research. All of this presents a grim picture and a worrisome outlook. However, before I go ahead with my discussion on specific aspects of science, mathematics and engineering education, I would like to offer several cautionary notes on how we proceed from here.

- The range of problems is so broad and their roots so deep that we may be tempted to throw up our hands and say "let each school district or state worry about its own special problems. It's much too complicated to do so nationally." Yes, the states and the schools have a central role but, as I will argue, the federal government also has a vital role to play.

- The gravity of the problems may lead to political pressures for rapid action -- of any kind. My concern is related to our national predilection for "short-term" solutions for

problems of any kind.

• I am concerned that the growing linkage between our international competitiveness and education might become the only reason for supporting a broad, national effort in education. Our efforts to improve the quality of our educational system should be more broadly based than on this one dimension. While the connection is important, and it is reasonable to argue for increased educational support on such grounds, we must not lose sight of other objectives such as those related to the quality of life -- as a nation and as individuals.

Budget Overview of NSF and the Department of Education

A review of the total budget numbers for NSF and the Department of Education reveals that:

• On what seems to be a definite overall positive note, the NSF shows a proposed increase for a newly defined informal grouping of programs called "education and development of human resouces." Its budget numbers show an increase of $91 million from $182 million in FY 1987 to $273 million in FY 1988.

• On the strongly negative side -- at least from a budgetary point of view -- is what seems to be a virtually total withdrawal of the Department of Education from science and mathematics education. However, almost worse than the withdrawal has been the policy instability exhibited in implementing the Education for Economic Security Act (EESA) of 1984.

It is difficult to understand what anybody hopes to achieve in a program that shoots up to $100 million in FY 1986, drops to

less than $80 million in FY 1987 and then to zero for FY 1988. Moreover, congressional insistence on a formula approach to grants has led to partitioning the total funding into what often became ineffective small grants of a few hundred dollars. Surely we can do better in terms of stability, priority setting, and long-term commitment to solving serious problems in the areas of science and mathematics education.

The NSF Five-Year Strategic Plan for Science and Engineering Education

We have reviewed NSF's "Strategic Plan FY 1987 -FY 1991: Enhancing the Quality of Science, Mathematics, and Engineering Education in America," dated February 10, 1987 which was recently submitted to the Congress as required by the Education for Economic Security Act of 1984 (P.L. 99-159). We find that:

- It represents important steps in the right direction and seems to draw carefully upon the results of the many studies and reports of recent years concerning science, engineering and mathematics education.
- It describes in considerable detail the kinds of activities and programs which will be necessary for our nation to undertake in attacking and solving serious educational problems, and presents them in an NSF context. The listing is rather complete.
- It does not, however, provide a clear statement of balance or priorities of science and mathematics education either as part of the total NSF program and budget or among the

various parts of the "education and development of human resources." Specifically missing are plans beyond FY 1988, including objectives and general budget targets over the five-year time horizon.

We hope that it will be possible for NSF to extend its analysis and planning in these areas when it eventually receives the strategic studies required by the Congress over two years ago. On this point of strategic planning we do think that NSF has come a long way in the past several years. Director Bloch and the National Science Board are to be commended on this score.

Some Long-Term Perspectives on the Current Budgets for Science and Engineering Education

It may be useful to review in roughly chronological order several historical perspectives on how we came to our current state of affairs. It is essential to understand that in one form or another we have been debating issues related to science and mathematics education for at least three decades.

- Just thirty years ago, in response to Sputnik, we reacted with alarm to what was seen at the time as a crisis of colossal proportions. One of our responses, along with large new investments in space research and technology, was to make large, new investments in science and mathematics education -- through NASA, the Department of Defense, and the National Science Foundation. (A landmark piece of legislation was the National Defense Education Act of 1958.)

- However, after that initial spurt of funding, interest

and enthusiasm for support of science and mathematics education diminished, although during the 1960s education was allocated a sizeable part of the total NSF budget -- in the 27-35 percent range --peaking at a level of $135 million per year in 1968 (See Table 1).

- During the 1970s, interest and enthusiasm continued to decline -- except in certain congressional circles such as your Subcommittee. You became one of the guardians and guiders of the science education program.

- Also, during the mid-1970s science education -- particularly certain curriculum development efforts -- became embroiled in political controversy as several social science courses were attacked by various political and religious groups. Congress acted imprudently, I think, by terminating support for all curriculum development by the NSF. We are still paying the price in our schools for that turn of events in the form of outmoded and ineffective texts and learning materials.

Another part of the price we paid as a nation for pulling out of curriculum development efforts was that we lost the momentum and value of faculty from research universities being involved in the development of curricula and related materials. I believe it essential that the research community be seriously involved in these efforts. This involvement brings together both researchers and educators in ways that benefit both groups and their work. These interactions also provide ways for linking and grounding research knowledge with practical applications of

that knowledge in schools.

• As the 1970s drew to a close, investment in science and mathematics education remained in the "backwaters" and the scars from the political battles of the mid-70s still showed. Yet evidence was beginning to mount that all was not well in science and mathematics education. Further, a new dimension was added to growing general concern: problems in engineering education.

• With the coming of the 1980s and the Reagan Administration, there was strong opposition to the previous role of the federal government in education. There was a determination to eliminate any federal role in science, mathematics and engineering education at NSF or anywhere else in the federal government. Thus was set into motion the series of decisions which led to the near demise of science education at NSF, except for the graduate fellowships.

• Only through the intercession of Congress -- Democrats and Republicans alike -- was nearly a total elimination of education averted at NSF. But very little in the form of organization or programs survived in 1981 and 1982. Mainly through Congressional prodding and the support of a few Administration officials, the science, mathematics and engineering education areas at NSF have been gradually recovering -- far too gradually in the view of many observers, including ourselves.

• Some observers and participants point to the fact -- noted above -- that in earlier crisis years science education

accounted for at least 25 percent of the NSF budget. Drawing on that benchmark, and concluding that today's problems are as serious as those in the 1960s, it is argued that the NSF science and engineering education budget should be in the range of $400 million in the FY 1988 budget as compared with the $115 million requested. It is also observed by some that reports of the National Science Board and other responsible parties have identified needs for various programs which would likewise add up to about $400 million at this time for FY 1988.

• This chronology clearly shows that science and mathematics education -- and more recently engineering education --have a history of "starts and stops," changing focus, and policy instability. As we look at the current situation there is little doubt that we have been in a low investment mode for a long period of time. Major investments over an extended period of time aimed at achieving agreed-upon objectives will be necessary if we are to have any hope of achieving significant progress in solving the array of problems facing us.

A key consideration for Members of the Committee and your colleagues in the Congress is a judgment on how serious is the educational crisis in this country with respect to science, mathematics and engineering education. A question needs to be asked: "Are things as bad as they were in the late 1950s and early 1960s? Or have we made significant progress in spite of the currently documented problems?"

My own view is that we have made progress. Although grave

problems exist, things are not as bad as they were in those distant years of the late 1950s. And most surely, we need to avoid the "crisis mode of response" which followed Sputnik. More directly, we do not need crash, catch-up programs aimed mostly at overtaking the Japanese or the Russians or other U.S. competitors.

Of far greater value, I think, would be a policy of sustained and substantial commitment by the federal government in a catalytic role. The focus of this role over the next ten to twenty years could be to make specific advances and improvements along a broad front in cooperation with the states and localities. Perhaps a model -- in terms of the long-term commitment but without the large federal financial role --could be the national interstate highway system we committed to during the Eisenhower Administration.

Over thirty years later we are still working at meeting that commitment, but the magnificent achievements have helped transform the country. Such a federal commitment in science, engineering and mathematics education would serve as the catalyst for comparable sustained effort on the part of the states, localities and private sector parties.

Specific Comments in the FY 1988 Budget

In reviewing the FY 1988 budget request in the context of the five-year strategic plan discussed earlier, we find ourselves rather puzzled. While we acknowledge the NSF presentation which shows the earlier mentioned increase of $91 million for

"education and development of human resources," we are concerned to see that no increase whatsoever has been allocated to pre-college education.

While the support for pre-college education appears in the text of the five-year strategic plan and in the public testimony of Director Bloch before your Committee, the proposed budget numbers for pre-college science and mathematics education do not reflect an appropriate level of budgetary commitment. While we are not calling for massive "Sputnik-like" federal action, it is important to acknowledge the vital need for significant responses and investments to cope with the serious deficiencies which have been amply documented time after time in recent years at the pre-college level.

Moreover, aside from the intrinsic need issue, there is the message sent by the "no-growth" action. In a environment of high growth rates throughout much of NSF's budget, there is the inevitable conclusion about the relative lesser importance of pre-college education. The NSF has had enough problems in the past of dealing with the perception that it really did not want to be bothered with this responsibility. Since this does not seem to be the case under the current NSF leadership, we are led to conclude that the "no-growth" decision was a mistake which the agency would cooperate with the Subcommittee in redressing.

The drastic drop-off in pre-college support for science and mathematics education by the Department of Education is one more reason why we must be concerned about the "no-growth" decision

for pre-college programs in the NSF's budget request.

It is time to acknowledge firmly and unequivocally that national policy should be to help establish, nuture and encourage the development of a consistent, integrated program of science and mathematics learning from kindergarten through high school. There must be a commitment to persist in our programs at the federal level long enough for change to occur, especially in the areas of curriculum development, teacher training, and the research base in education. Particular emphasis must be placed on the R&D portion of the science education budget.

With respect to curriculum development, we cannot just mail out new curriculum materials to teachers and expect that the materials will be utilized. We know that approach does not work. New training programs must be devised and implemented in cooperation with the states and school districts. Closer attention must be given -- using research results -- to what works best in teacher training. And given the scarcity of resources, we must avoid methods of teacher training that are not cost effective. More emphasis needs to be placed on an approach to teacher training which is based on continuing education on school premises or in local areas. We need to focus on the design of technologies aimed at upgrading knowledge of content and the methods of teaching it <u>within</u> the school and classroom. NSF has an array of capabilities that would be important to such an effort.

It is quite possible to use the concept of "resource

centers" for reaching out with continuing education for local school and school district teachers. For example, it might be worthwhile to explore the use of a model based on the current Engineering Research Centers as one way of reaching out to high schools.

While there is no question -- nor was there ever one despite what some critics have said in the past -- that this leads to federal "control" of education, it does underscore the importance of the federal government in performing educational research and development, investing in curriculum development, and pioneering in new teaching and learning appproaches.

The plain facts are that the fifty states and the 16,000 school districts in this country cannot replicate individually all such activities. Yet the implementation of specific programs will rest firmly in the hands of the local schools, their school boards and the states.

At this point I might address a specious argument sometimes used in opposing a federal role in education: since the local school systems involve expenditures of many billions, how can the federal government expect to have any impact with the expenditure of relatively few NSF dollars. Such arguments ignore the fact that the great part of those billions is for teacher and administrative salaries. The amount spent by any given school district on research or course development for science and math education -- or any other subject -- is tiny or non-existent. This is where the federal effort has high leverage and fills an

urgent need in its role as a catalyst.

Further, I would underscore the obvious: pre-college science and mathematics education is where we must begin to insure an adequate flow of informed citizens, candidates for careers in science and engineering, and those who will be in the management and professional ranks of organizations which will depend on advances in science and technology for their well-being and survival.

I want to emphasize that in order for students to enter programs in science and engineering they must have gone through demanding programs in high school. And that for them to have chosen such programs in high school, they must have had the kinds of programs and teachers at the middle school level that provided the right kind of motivation.

Let me now turn to another facet of our "education deficit:" those issues surrounding the education of women and minorities in science, mathematics and engineering. These issues have been discussed and debated in terms of equity and fairness for more than a decade. While equity and fairness are still important, it is becoming clear that national need for the talents of women and minorities in science and engineering is becoming the driving force.

As Figure 1 shows, the demographic trends to the year 2000 show a significant dropoff in the numbers of 22-year olds and 30-year olds in the U.S. population. This is the pool from which we obtain our scientists and engineers. Figures 2 and 3 show

dramatic reductions in the production of scientists and engineers at all levels if we maintain 1984 participation rates.

There is no doubt that we must tap this pool of candidates if we are to have enough qualified scientists and engineers in the future. We must continue to reach for answers to the under-achievement problems and the under-participation of women and minorities in science and engineering. This means we need on-going research on these issues; we need the development of models and programs which will work. Also, we need more evaluation of various models and dissemination of the results on "what works and why."

Key practical questions include: how can we encourage greater experiences in science and mathematics by young people in these groups? How are we going to get more science and mathematics teachers from the talent pool of women and minorities? NSF has done some exemplary work in the area of women and minority participation but it may be time for a more active, aggressive approach to finding answers to the kinds of questions I have just posed.

To summarize on science, mathematics and engineering education:

- We support the NSF budget request and believe it represents a sound move as part of an overall program for improving the state of our economy. Only with respect to the plans and budget request for pre-college education do we differ from the Administration's request. We believe the case is

overwhelming for a moderate increase to the range of $100 million as the beginning of a long-term commitment. Given the unlikely event that this suggested increase can be an "add-on," the offset could be taken in the form of proportional reductions in other NSF program areas.

o NSF should set a number of specific goals, either alone or in cooperation with the Department of Education (depending on the future role of the Department), in science, mathematics and engineering education. Examples of such goals could be:

(1) In ten years achieve a significant increase in student performance in mathematics so that we rank closer to the top internationally. Not only would this achievement give us a stronger underpinning for careers in science and engineering but also would permit us to escape the acute embarassment we should be feeling over our present low performance.

(2) In ten years achieve a complete overhaul and modernization of mathematics and science curricula in grades K through 12.

(3) By the year 2000, in close cooperation with the states and school districts, develop and make available appropriate equipment to support effective science teaching in grades K through 12.

(4) Within five years develop a core of regional "resource centers" for science and mathematics teachers in all parts of the country. Continue to expand such centers in number and capabilities over the next fifteen years.

(5) Develop the programs that will, within ten years, lead to a doubling of the number of science and mathematics teachers from minority groups.

(6) Explore the feasibility of networking science and mathematics teachers along the lines of researchers in NSFnet.

(7) Establish and support for the long-term an adequate R&D base in science, mathematics and engineering education.

Such suggestions are only illustrative. We strongly recommend that the pending strategic planning of the NSF be made more explicit in terms of objectives, priorities and proposed budgets. Moreover, unless this strategic outlook is adopted and supported nationally, the prospects for any significant progress in solving the previously outlined problems are not promising.

The states and school districts can do and, indeed, are doing much to improve the overall quality of education by increasing teacher salaries, raising standards for teachers and students alike, and by modernizing school organizations and physical plants. Yet, there remain the crucial federal roles as the performer of education research, the catalyst, the networker, and the supporter of the development of new materials and learning methodologies.

Instrumentation

The enormous set of problems associated with inadequate and outmoded equipment and instrumentation has been amply documented in a variety of studies. At this time we will not develop the case further, but do wish to express our support for the NSF

position in stressing continued growth as shown in Figure 4.

Individual-Center Research Awards

Considerable attention and concern has been directed to the issue of an appropriate balance between individual and center (or group) research awards. While I will not include a full analysis of this particular issue in these remarks, the following represents a brief summary of my views:

(1) I do support the NSF initiatives in establishing centers and supporting departmental (or "mini-centers"), team and group awards. NSF director Erich Bloch and the National Science Board are moving in the right direction -- subject to a number of the caveats outlined in my testimony.

(2) As I consider the balance among the overall components of NSF resource allocations so far during the 1980s, I do not see cause for alarm about the data as reflected in Figure 5. While the percentage allocation for individual investigators has dropped, the overall budget increases have led generally to absolute increases in available resources.

(3) At the same time, however, I wish to reaffirm my own belief and commitment to the need for a strongly supported individual investigator program. This research constitutes the basic building blocks of a strong, healthy, productive science and engineering system. I think I would begin to express concern and alarm if major realignments in future resources resulted in more than modest relative declines in individual project support -- in an overall sense and in specific fields. In any event, I

would urge continuing to support growth of individual project research at levels at least commensurate with inflation.

(4) One last consideration regarding centers and individual project awards is that individual grants are the best way to assure widely dispersed investigators of the potential for continuing to work. And while I support the use of centers we must be careful about getting to a state of resource allocation and funding mechanisms in which too many investigators would be faced with the choice of congregating in centers or not participating in research of any consequence.

(5) In closing, I'll return to where I began. The questions of balance are vital but they are not likely to have simple answers. It is in pluralism of all kinds -- funding, performers, and research mechanisms -- that we find the sources of vitality and success in American science.

Thank you, Mr. Chairman and Members of the Committee, for the opportunity to express our views and for your support of science and engineering over the years.

TABLE 1

Estimated National Science Foundation Science Education Obligations By Function, By Year
(in millions of dollars)*

Fiscal Year	Total NSF dollars	Total SE dollars	Percent SE of Total	Functions** R&D*** %	R&D $	Students %	Students $	Teachers %	Teachers $	Institutions %	Institutions $	Science and Society %	Science and Society $
1952	3 47	1 54	44 4	0	0	99 7	1 535	0 3	0 005	0	0	0	0
1953	4 42	1 41	31 9	0	0	98	1 38	2	0 03	0	0	0	0
1954	7 96	1 89	23 7	0	0	95	1 796	5	0 09	0	0	0	0
1955	12 49	2 10	16 8	3	0 06	88	1 85	10	0 21	0	0	0	0
1956	15 99	3 52	22 0	0 4	0 01	67	2 36	32	1 13	0	0	0	0
1957	38 63	14 30	37 0	7	1 00	21	3 00	72	10 30	0	0	0	0
1958	49 97	19 20	38 4	9	1 73	22	4 22	69	13 25	0	0	0	0
1959	132 94	61 29	46 1	14	8 58	24	14 71	62	38 00	0	0	0	0
1960	158 60	63 74	40 2	14	8 92	25	15 94	60	38 24	0	0	0 5	0 32
1961	174 99	63 44	36 3	15	9 52	24	15 23	61	38 70	0	0	0 5	0 32
1962	260 82	83 60	32 1	12	10 03	24	20 01	61	51 00	3	2 51	0 4	0 33
1963	320 75	98 72	30 8	15	14 81	27	26 65	55	54 30	3	2 96	0 4	0 39
1964	354 58	111 23	31 4	15	16 68	30	33 37	51	56 73	4	4 43	0 4	0 44
1965	415 97	120 41	28 9	13	15 65	36	43 35	44	52 98	7	8 43	0 3	0 36
1966	466 43	124 30	26 7	13	16 16	42	52 21	39	48 48	6	7 46	0 1	0 12
1967	465 10	125 82	27 1	17	21 39	38	47 81	38	47 81	6	7 55	0 3	0 38
1968	495 00	134 46	27 2	16	21 51	36	48 41	37	49 75	10	13 45	0 2	0 27
1969	400 00	115 30	28 8	18	20 75	37	42 66	34	39 20	12	13 84	0 2	0 23
1970	440 00	120 18	27 3	15	18 03	38	45 67	37	44 47	9	10 82	0 2	0 24
1971	513 00	98 81	19 3	23	22 73	38	37 55	35	34 58	4	3 95	0 4	0 40
1972	622 00	86 10	13 8	33	28 41	28	24 11	28	24 11	12	10 33	0 8	0 69
1973	645 74	62 23	9 6	34	21 16	34	21 16	21	13 07	11	6 85	1	0 62
1974	645 67	80 71	12 5	36	28 79	22	18 13	25	19 96	14	11 61	3	2 42
1975	693 20	74 03	10 7	35	26 65	26	19 00	24	17 90	13	10 00	2	1 49
1976	724 40	62 50	8 6	17	10 63	36	22 50	6	3 75	37	23 13	4	2 50
1977	791 77	74 30	9 4	15	11 15	31	23 03	11	8 17	38	28 23	5	3 72
1978	864 91	73 96	8 6	12	8 83	29	21 45	14	10 35	38	28 10	7	5 18
1979	928 40	80 00	8 6	14	11 20	28	22 40	13	10 40	36	28 80	8	6 40
1980	996 25	77 19	7 7	18	15 25	25	21 18	14	11 86	34	28 80	9	7 62
1981****	1 041 80	70 70	6 8										

* The functional categories of obligations are development as follows Students includes programs such as fellowships and pre-college student science training Faculty includes programs such as teacher institutes and faculty short courses Institutions includes programs such as ISEP (equipment purchasing), LOCI (Local Course Improvement), and CAUSE (Comprehensive Assistance to Undergraduate Science Education) Science and society includes programs for improving the public understanding of science and studying the ethical issues in science and technology

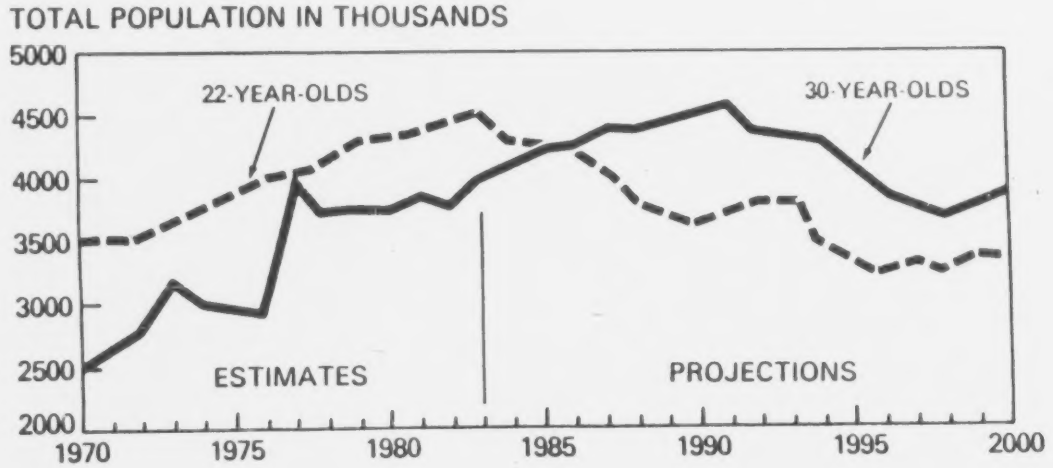
** Most R&D development projects received most of the R&D funding

*** 1981 Breakdown of obligations not available at time of printing

Source Directorate for Science Education, National Science Foundation, unpublished data

FIGURE 1

PROJECTIONS OF 22-YEAR-OLDS AND 30-YEAR-OLDS IN THE U.S. POPULATION



SOURCE: BUREAU OF THE CENSUS.

FIGURE 1

FIGURE 2

FUTURE S/E BACCALAUREATES, ASSUMING CURRENT PARTICIPATION RATES

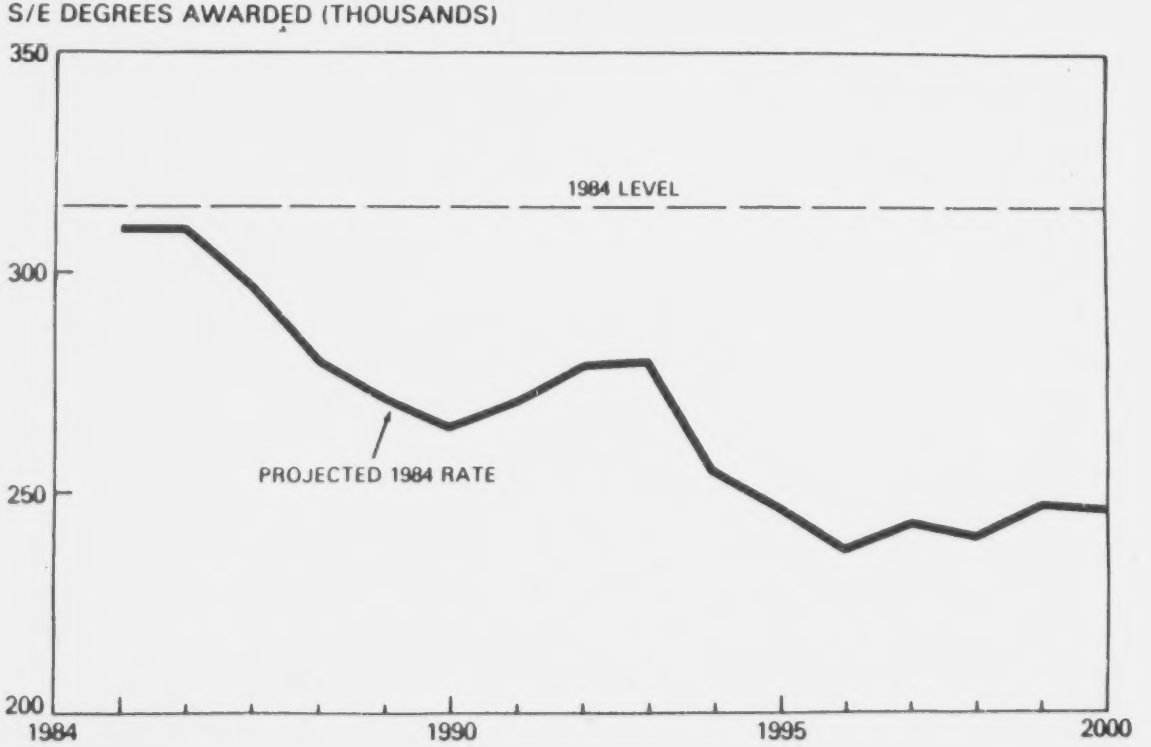
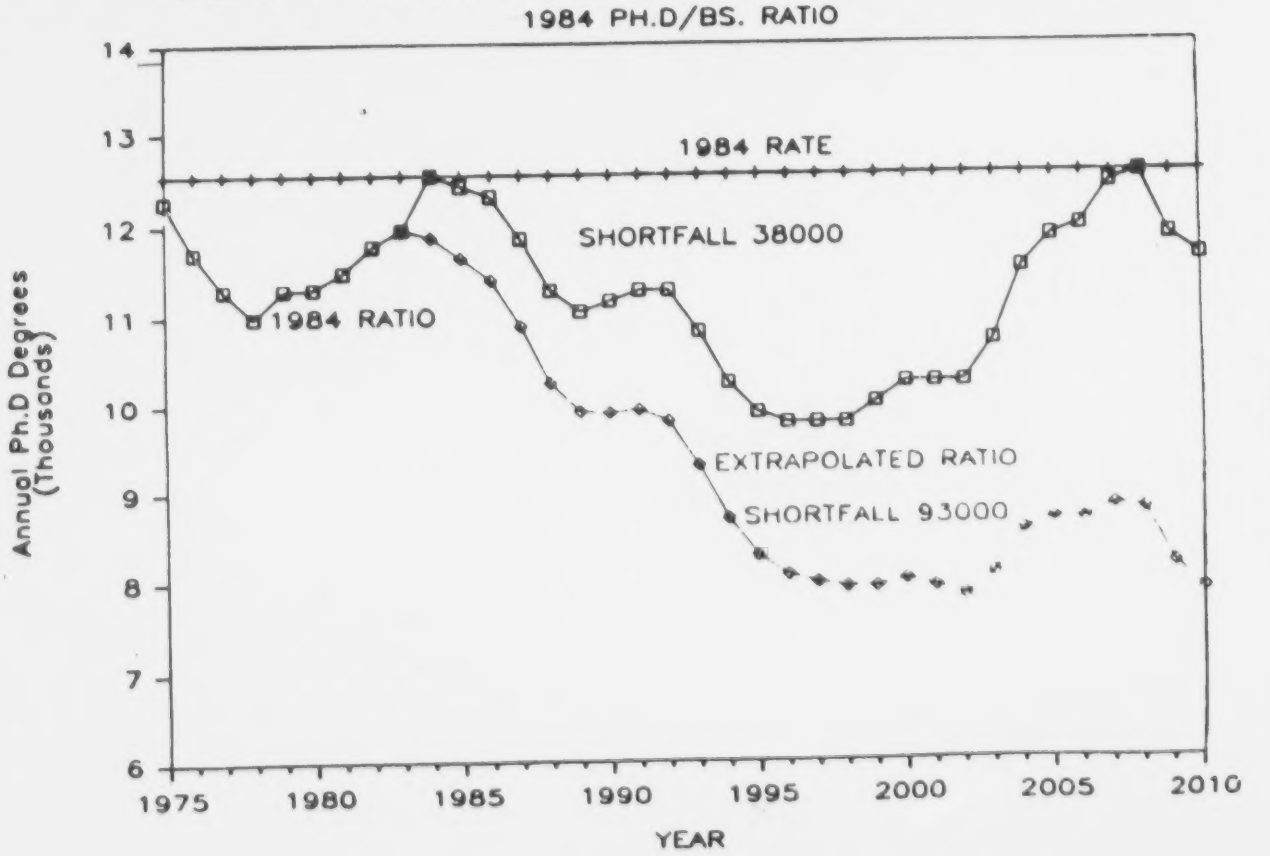


FIGURE 3

S&E PH.D. PRODUCTION RATE WITH



140-9/86

FIGURE 3

INSTRUMENTATION
FY 1983-FY 1987

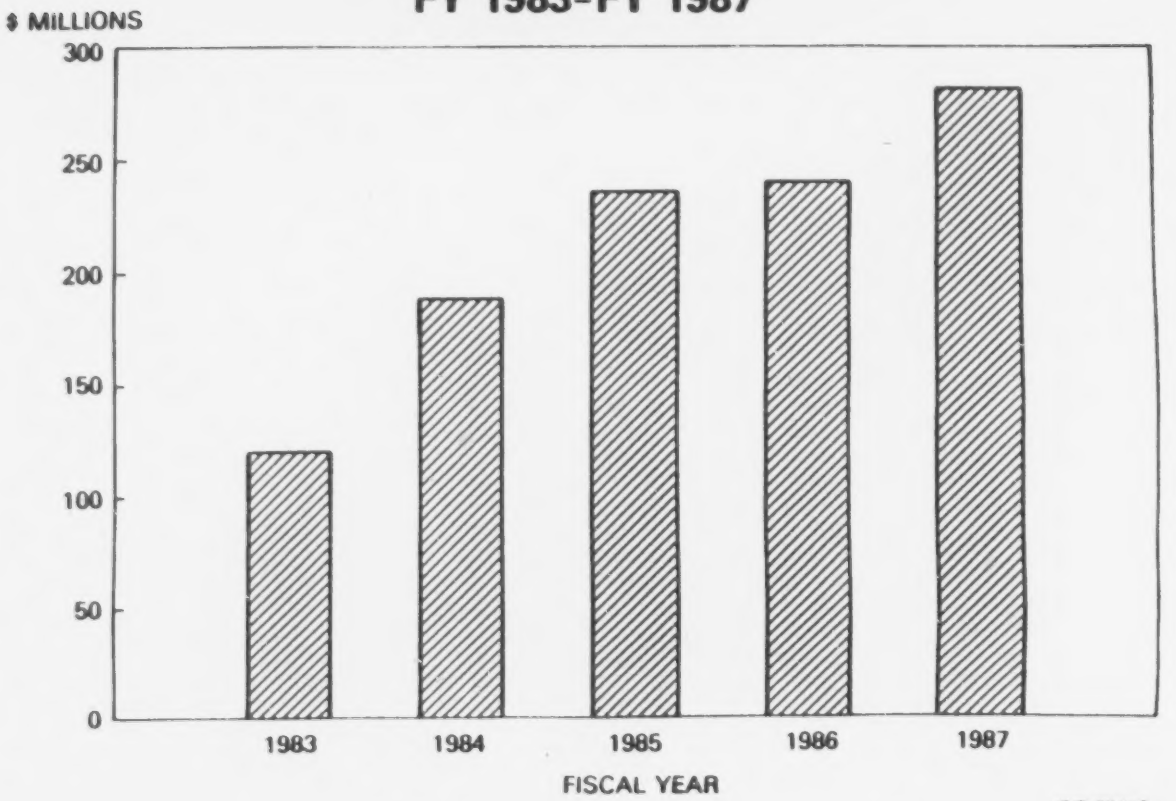
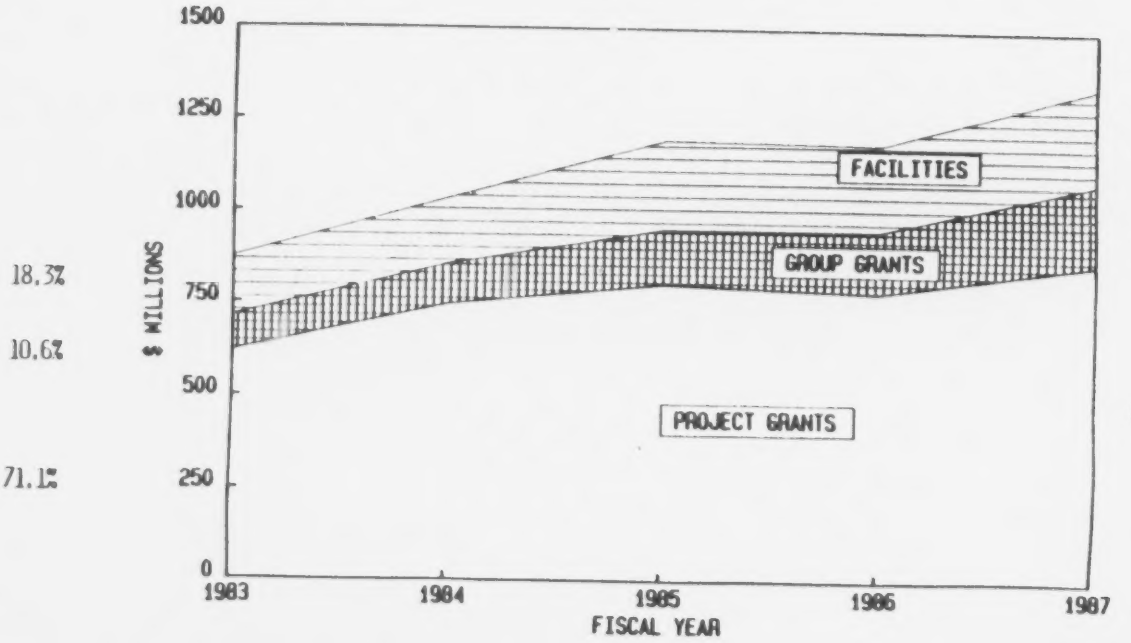


FIGURE 4

NATIONAL SCIENCE FOUNDATION
PROJECT BALANCE

FY 1983 - FY 1987



* INCLUDES MPS, AAEO, BBS, ENG, & ASC ONLY

FIGURE 5

PUBLIC AND SCIENTIFIC AFFAIRS BOARD

AMERICAN SOCIETY FOR MICROBIOLOGY

1913 I Street, N.W.
Washington, D.C. 20006
Telephone: (202) 822-9229

April 8, 1987

The Honorable Edward Kennedy
Chairman, Senate Committee on Labor
and Human Resources
U.S. Senate
Washington, D.C. 20510

Dear Chairman Kennedy:

The American Society for Microbiology (ASM) wishes to comment on the Fiscal Year (FY) 1988 budget for the National Science Foundation (NSF). The ASM is the largest single biological life science organization in the world with an active membership of about 35,000. Many of these individuals are engaged in biological research and a sizable number are recipients of grants administered by the NSF. A large number of areas are represented in their interests, including molecular genetics, biotechnology, photosynthesis, nitrogen fixation, regulation of gene expression, immunology and ecology.

Looking ahead at the future of the National Science Foundation, and planning for the role the NSF should play in supporting American science, the Administration has proposed that the budget for the NSF be doubled over the next five years. As an important first step in this direction, the Administration is proposing a 17% increase over the FY 1987 allocation for FY 1988, and looks ahead to a 14% increase for FY 1989. The ASM heartily endorses this recommendation and supports the objective of increasing our national level of commitment to the NSF in order to realize more effectively and completely the potential for excellent science in America.

A proposed increase of 17% for 1988 might at first sight seem overly generous at a time when the size of the federal budget deficit causes concern, calling for the exercise of responsible budgetary stringency. However, the NSF is one of the few government agencies responsible for generating new scientific knowledge, providing this country with the tools needed to aggressively compete with other nations in the arena of scientific discoveries and their applications in both agriculture and industry. We cannot afford to slight this important part of our national effort. The recent White House Science Council Report on the Health of U.S. Colleges and Universities concluded that today's federal investment in universities is inadequate to meet the demands for developing talent and new knowledge. The total dollar increase requested for FY 1988, $270 million, is a relatively small amount in terms of the federal budget as a whole, and is certainly a small amount when measured in terms of the invaluable returns that will be harvested in the form of increased knowledge and understanding in important areas of science. We fully concur with former House Science and Technology Committee Chairman Don Fuqua's recommendation that "Basic research, which comprises only .8% of the federal budget, could be increased substantially without reaching a point of diminishing returns."

The NSF's Biological, Behavioral and Social Sciences Directorate (BBS) supports a significant amount of the research done in the United States on basic mechanisms of cells and the molecular basis of life. It supports about 90% of the basic environmental biology research at colleges and universities. The NSF biological sciences program has contributed to a better understanding of the structure, function and regulation of genes and the use of gene transfer techniques for the potential improvement of economically important plants. The program has generated new knowledge from biochemical, cellular and physiological research in the plant sciences, specifically in the area of photosynthesis and nitrogen fixation and plant resistance to stress. Genetic engineering techniques are being developed which may lead to increased food production for the world. Studies in the utilization of biological systems and biomass conversion for the production of chemical materials promise alternate domestic sources of energy and critical materials of biological origin in the future. NSF's role in supporting fundamental research in microbiology and molecular biology is crucial to the rapid development of biotechnology which will strengthen our economy.

The following are just a few examples of significant advances that NSF support of high quality science has led to in recent years:

- a gene that codes for light production was transferred into the genetic material of a complex multi-cellular organism. The firefly gene promises to be a valuable rsearch tool for tracing gene expression within living systems, for learning more about plant development and for genetic engineering in plants, leading to new technology which can be used by the biotechnology industry for developing new products, e.g., pharmaceuticals and more productive, more nutritious and disease resistant crops;

- the discovery of a unique bacterium Heliobacillus mobilis that acts as a natural fertilizer, a finding which represents a giant step in the evolution of ancient life and may also be useful in modern agriculture as a living nitrogen fertilizer;

- the first automated DNA sequencing machine was developed, an instrument that will aid in finding the underlying basis of cancer and genetic diseases and accelerate basic research on how life operates at the molecular level;

- the structure of a common cold virus was determined rapidly through the use of a super-computer, a finding which could pave the way

for the development of vaccines for colds and other human ailments because it provides insight into how a virus works.

We wish to emphasize that individual investigator-initiated research grants play a critical role in ensuring that significant advances in scientific knowledge continue to be made. New ideas and new solutions arise largely from the efforts and creative energies of individual scientists supported by individual research grants. Continued and increased support for this essential avenue to future discoveries is needed if this country is to maintain a position of international leadership in science.

Our analysis of the budget for the NSF Biological, Behavioral and Social Sciences Directorate shows an unfortunate trend which has developed over the years at NSF. Both the proportion of proposals received that were able to be funded and the size (in buying power) of the individual awards has declined. By awarding insufficient numbers of grants, potential good science was not supported and was lost; by decreasing the buying power of the grants that were awarded, in many cases the ability to carry out a project was compromised, and as a result the project was weakened.

Recently some effort has been made to reverse this trend. However, there is still a long way to go to make the most of the opportunities we have before us. At present, some programs within BBS are able to make awards for only 10% of the proposals received, and that only by dint of economizing by paring down the budgets of many of the awarded grants. Some very fine proposals have to be turned away. In order to take full advantage of the research potential of the scientific community in this country, both the numbers and the amounts of individual research grants should be increased substantially, to even a greater extent than is specified in the Administration's proposal.

An average grant in the biological sciences funded by the NSF supports limited personnel and supplies and leaves little or no funding for the acquisition or replacement of relatively low-cost instrumentation, which is the sort of equipment that is used heavily and cannot be shared with other labs. Most research in the biological sciences is carried out with modern techniques and equipment which are more expensive than in the past. At their present level of funding, grants awarded by BBS are below the level necessary to maintain an efficient program of research and do not serve as a mechanism for replenishment of relatively low-cost pieces of equipment (under $100,000).

The BBS plans to increase the average award from $70,000, estimated for FY 1987, to a goal of $78,000 for FY 1987, a worthy objective. However, on the other side of the coin, while planning to increase the size of the awards, the proportion of proposals that will be funded has been reduced.

We believe that even now many fine proposals fail to win support; to reduce the proportion awarded even further would leave even more worthy projects without support. To start a trend in the other direction, we propose that the proportion of proposals to be funded within the subactivities of the Molecular Biosciences, Cellular Biosciences and Biotic Systems & Resources in FY 1988 be restored to the FY 1986 actual level plus a 5% increase. This action would permit funding approximately 720 additional proposals. To fund them at the FY 1988 level would require addition of approximately $63.3 million, distributed among these three subactivities. In our view, such a relatively small, targeted increment would yield disproportionately great benefits in relation to the size of the outlay.

Several initiatives have been emphasized in the plans for strengthening the NSF. Aside from the initiatives in the field of Engineering, resources are committed to be used to support Biotechnology, an area where funding has been inadequate to ensure continued US leadership. Recommendations are made to create a number of shared-user instrumentation facilities as well as a small number of sophisticated multi-disciplinary research centers.

Attention is also focussed on the need to expand and improve science education and the training of future scientists. These needs are addressed at steps extending over many stages of education, from secondary school through college, graduate school and at the postdoctoral level. We agree with the need to improve the scientific literacy of the public and the need to train well the next generation of scientists, and we support the measures that are proposed. Data from several government sources indicate a shortage of certain types of biological scientists and support predictions of greater shortages in certain fields in the near future. It is essential to train additional individuals in the biological sciences to take advantage of the current expansion of research opportunities.

Each of the worthwhile initiatives in the NSF budget proposal requires and merits budgetary support. However, in our view such financial support must be in addition to, not instead of, significantly increased support of the backbone of the nation's scientific endeavor, the individual investigator-initiated research project. While we support the concept of addressing the need for university-based multidisciplinary, multi-investigator research, we are concerned that without substantial growth in the NSF budget in the future, the proposed new science centers could absorb an increasing share of NSF resources and compete with the individual investigator initiated research grant for scarce research dollars. Therfore, we urge that a continued emphasis be placed on individual investigator initiated research grants and that increased NSF funding be obtained and used to establish multidisciplinary centers. As a part of the initiative to establish the new centers, we recommend that a mechanism be set up to monitor and evaluate their effectiveness.

The ASM asks that each of these considerations be weighed as decisions are made by the Congress regarding the authorization for support of the National Science Foundation in 1988.

The ASM appreciates the opportunity to comment on the FY 1988 budget request for NSF and stands ready to provide additional information or assist in any way possible during the budget process for NSF.

Sincerely,

Jean E. Brenchley

Jean E. Brenchley, Ph.D.
President
American Society for Microbiology

Harlyn O. Halvorson

Harlyn O. Halvorson, Ph.D.
Chairman, Public and Scientific
Affairs Board, ASM

Monica Riley

Monica Riley, Ph.D.
Chairman, Committee on Genetic and Molecular
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Senator STAFFORD. And with that, we will proclaim the Committee is recessed.

[Whereupon, at 3:40 p.m., the Committee was adjourned.]

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